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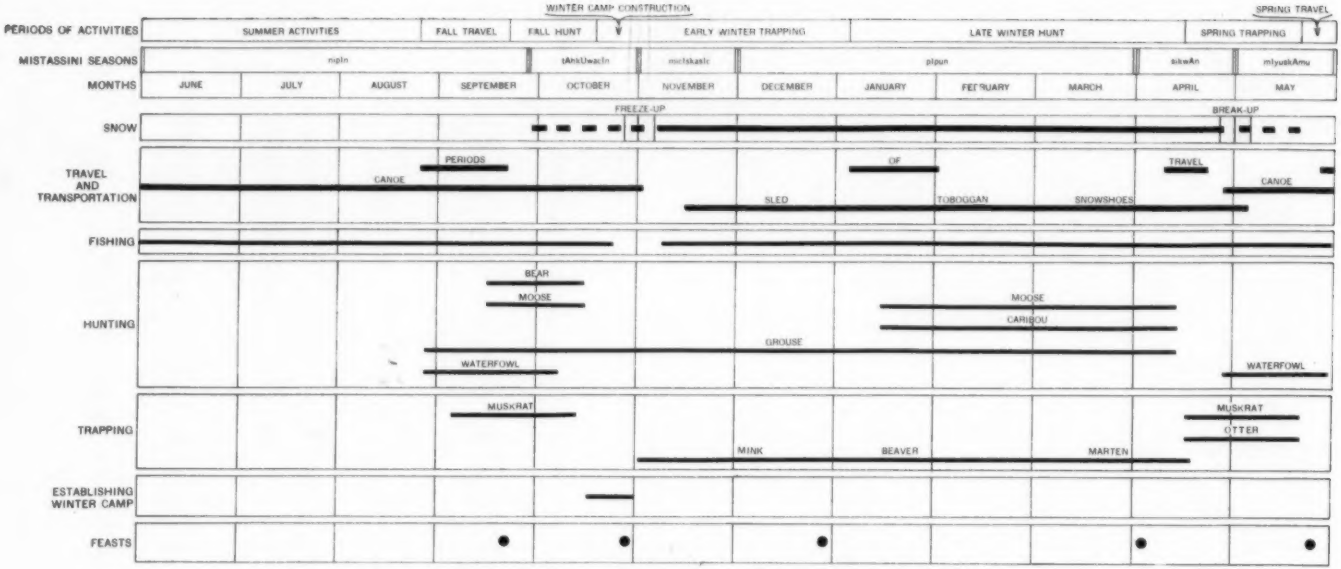

Fig. 1. Seasonal activities and movements of the Mistassini Indians.

THE YEARLY CYCLE OF THE MISTASSINI INDIANS*

Edward S. and Jean H. Rogers

THE following description of the yearly cycle of activities of the Indians about Lake Mistassini in south central Quebec is based on thirteen-months' field work conducted by us during 1953 and 1954. We wish to thank the Arctic Institute of North America and the Office of Naval Research for their financial backing of the project. In addition, we wish to express our gratitude to the following individuals: Dr. Jacques Rousseau, Mr. Frederick Johnson, Dr. A. V. Kidder, Mr. Wendell S. Hadlock for their support of the project at its inception; Dr. W. W. Hill, Dr. Stanley Newman, and Dr. Harry Basehart for their assistance in the analysis of the field data; Mr. and Mrs. Wilfrid Jefferys, Mr. Jules Sesia, Mr. Jimmy Stephenson, Mr. Ron Thierry for their help and hospitality during the field work. Our greatest debt, however, is to Alfie Matoush and his hunting group of thirteen members, who allowed us to accompany them to their trapping grounds for the winter of 1953-4. Our 9 months of intimate association with this small group made the following study possible.

The Mistassini recognize six periods or seasons of the year, determined on the basis of seasonal climatic changes. The seasons are *pIpun, sikwAn, mIyuskAmu, nipIn, tAhkUwacIn,* and *micIskasIc.* Since there are climatic fluctuations from year to year, the dates for the beginning and end of each period vary.

pIpun, "winter", includes the months of December, January, February, and part of March. During this period the temperature is rarely high enough to melt the snow. This term is also employed to mean "year". Beginning in March or early April the snow begins to melt during the day, and *sikwAn,* or "early spring", is said to have begun. This season lasts until break-up, when the ice leaves the lakes and rivers. Today the period is considered by some Mistassini to begin with Easter regardless of weather conditions. Following break-up and extending for a few weeks, generally in the month of May, is *mIyuskAmu* (literally "good water"), or "late spring". The period of June, July, August, and part of September, is known as *nipIn,* "summer". This season terminates when the ice begins to form

* These studies were aided by a contract between the Office of Naval Research, U. S. Department of the Navy, and the Arctic Institute of North America. Reproduction in whole or in part is permitted for any purpose of the United States Government.

about the edges of small ponds. A fifth period, *tAhkUwacIn*, or "early fall", begins at this time and lasts until the ice on the smaller lakes is just thick enough to walk upon, generally at the end of October or early in November. The last period, *micIskasIc* or "late fall", begins when the ice on the lakes has become too thick to allow a canoe to be forced through and is barely safe to walk over.

The seasonal activities and movements of the people conform only in part to the native seasons. Accordingly, on the basis of these activities and movements, the year has been divided into eight periods (see Fig. 1). The Mistassini imply these periods in discussing their yearly activities even though they do not have names for them. Seasonal feasts mark several of the periods. For convenience of presentation the eight periods are designated as follows: fall travel, fall hunt, winter camp construction, early winter trapping, late winter hunt, spring trapping, spring travel, and summer activities. Dates assigned to these periods must be somewhat arbitrary, since various factors influence the cycle. The most important are the annual climatic fluctuations, distances to the hunting territories, game resources of particular areas, and the health of the group members.

The fall travel period begins about the middle of August and continues until the middle of September, when the Mistassini are engaged in moving from the summer post at the south end of Lake Mistassini to their hunting grounds. Each hunting group, composed of several nuclear families with perhaps a few related dependents, travels as a unit under the informal leadership of one man, generally the oldest male. At the start of the trip other families may join the group for a day or two when their routes coincide. Travel used to be by birchbark canoe, but in recent years large freighter canoes and outboard motors have been employed. One canoe with a motor tows several others. Caches of gas and flour are sometimes made at various points along the route to facilitate the return trip in the spring.

During this period the Indians travel only in fair weather in order to safeguard the health of the small children. If weather conditions are favourable the group leaves in the morning between six and ten o'clock. When possible the day's goal is an old camp site of the previous year. Depending on circumstances camp is made at some time between noon and seven in the evening. Stops for meals are spaced about 3 hours apart. The leader of the group is always the last to leave the camp site, and generally his canoe is last in line. If a canoe is damaged, the entire party may stop until it is repaired.

When rapids are encountered the canoes are poled or tracked or equipment and goods are portaged. Sometimes women, children, and dogs are set ashore to walk, while the men negotiate the rapids with equipment and supplies in the canoes. Often the work of negotiating the rapids is done in relays. The supplies are transported ahead while the women and children remain in camp. The next day the camp is moved ahead of the supplies, which are then brought up to the new camp.

Only when absolutely necessary are supplies and canoes portaged. Along the frequently used routes of travel are well defined trails, which have been in use for centuries. Archaeological sites are common here. The trails rarely exceed 2 miles in length. Tumplines are employed for packing, with everyone in the group participating, even small children. A child who is old enough to walk over a trail will not go empty handed. Adults, especially the men, sometimes carry prodigious loads up to about 400 pounds for a strong man on a short, easy portage.

When a campsite is selected the canoes are beached. The first articles removed are the tents, stoves and axes. Each married man immediately erects his family's tent and stove while his wife gathers boughs. Once the tent is up, the women lay the floor boughs. A fire is lighted and food prepared if meal time is approaching. During warm weather the stove is generally erected outside the tent. Next, the bedding is removed from the canoes and usually carried to the tents by the women. The men cut saplings; these are placed on the shore, and the supplies are piled on them as they are unloaded. The empty canoes are drawn on shore and turned over, and the supplies securely covered with tarpaulins. The men now gather some wood if the women have not already done so. Sufficient bannock must be made by the women to supply the family until the next campsite is reached, if the group plans to travel the following day. The time required to set up camp, from the landing of the canoes until the bannocks are cooking on the stoves, may be as little as 1 hour. Fall-travel camps are located close to the water, except when an occasional camp is erected along a portage trail.

As soon as camp is established the personnel of the group may fish, hunt, or set snares if the time and location permit. The most important task is setting gill nets. Some of the fish taken are eaten within a day or two. The rest are partially smoked and dried and consumed within a week or two. Snares are set for rabbits; muskrats and ducks are hunted, and sometimes a search is made in the vicinity of camp for big game. Occasionally, blueberries are gathered by women and children.

The members of the hunting group normally reach their own land between the middle and end of September. Their arrival marks the beginning of the fall hunt. A base camp is established from which the men hunt big game, but it may be moved to another location after several weeks. Base camps are distinguished from travel camps by the erection of additional structures such as bedding racks, fleshing and beaming posts for the processing of hides, racks for drying meat, saw frames, cache racks for the ceremonial disposal of certain bones; they are located as close to good fishing grounds as possible. Since protection from the weather is not so important in the fall and spring, camp is often established within a mile of a place where nets can be set. In winter protection from the northwest wind is desired, often necessitating a camp location several miles from the nets. Old camp sites may be used for base camps during fall and spring, and sometimes one camp site is used during several successive years. This

is not usually true, however, of base camps used during the winter, when new lodges are generally constructed and camp sites are not used more than once during a period of some years.

During the fall hunt as much game as possible is taken, dried, and stored for the winter. The Mistassini leave the summer encampment early so as to take advantage of the favourable hunting conditions during the fall.

The men hunt each day, usually in pairs, occasionally individually. The principal animals sought are bear, moose, and caribou. When a kill is made and the meat has been processed, hunting may continue if time permits. If no kill is made the camp will be moved and re-established in another location. The men are gone during the day, generally from early morning until dark. They travel as much as 20 to 30 miles a day, going perhaps 10 miles from base camp and returning by another route. On occasion they leave the base camp for several days and establish a hunting camp 10 or more miles away, from which they make day hunts. A small canoe, pointed at both ends, is used for transportation where necessary, but much of the hunting, at least in the open boreal forest, is done on foot. In addition to hunting muskrats are trapped and occasionally ducks are shot.

In the past large quantities of whitefish and lake trout were taken. Fishing was sometimes continued into November. One informant stated that about a thousand whitefish were taken by his family and thoroughly dried for the winter. Nets were set at the mouths of streams and in shoal water around islands, since trout and whitefish come to these locations to spawn. At present both men and women set and tend the gill nets, but no attempt is made to take as many fish as in former years. The nets are examined every day or so and the fish secured are partially dried by the women. The fish are used by the men for food while hunting. (According to Burgesse (1945, p. 23), fall fishing at Mistassini was carried on communally before the hunters moved inland to their respective wintering places. This is perhaps correct in that certain families secured and dried fish for the trip inland, but we found no evidence of communal fishing.)

Women and children gather blueberries; formerly large quantities were secured, cooked, and dried for the winter. Recently less emphasis has been placed on berrying and the few gathered are made into jam, which is soon eaten.

A small feast is given before the fall hunt begins. (Formerly the food for this feast consisted of a beaver, which was first singed and then boiled (Lips 1947a, pp. 7-8); sometimes it was obligatory for the participants of the feast to remain until the entire beaver was eaten (Lipps 1947b, p. 389)). The men drum and sing, and if the drum "talks" and the drummers feel "good", it is believed that the coming winter will be successful. If a bear is killed before or during the fall hunt (or, for that matter, at any time of the year) another feast is held. This happens also when moose or caribou are killed.

When a successful hunter returns to camp he does not immediately advertise his success. If he returns by canoe he generally leaves his game

bag in the canoe for his children to bring to the tent and their excitement is usually the first indication that a big kill has been made, for the hunter will bring in his game bag a few tidbits, such as the liver and a small quantity of meat. All the men and older boys help to bring the meat to camp, unless it is decided to move camp to the kill, and for some days the entire group is occupied in butchering, hide working, and the cooking, drying, and packing of meat.

During the middle of October base camp is moved to a new locality, which is to be occupied until January. More substantial lodges are erected, often communal dwellings for the entire hunting group. Cache racks are constructed in order to store meat and supplies, as well as animal bones. Canoe storage racks are built and supply tents erected. Later other equipment is constructed, such as hide stretchers and toboggan planing boards. The work of erecting the camp takes from 1 to 2 weeks, everyone working from dawn till dark. When the operation is completed men and women concentrate on gathering a supply of firewood, which women and children later augment as need arises.

After the first winter base camp is erected a feast is held. This is a small one if the fall hunt has been poor and food is limited. The men sing and drum to predict their well-being during the winter.

In the last days of October or early November the lakes and rivers begin to freeze and the snow begins to accumulate. The period of freeze-up, which lasts only a week or so, marks the climatic shift to winter. Fish nets are retrieved to prevent them from becoming frozen in the ice. Nets are not used again until the ice is safe to walk over. During the winter the men examine the nets about once a week.

Formerly, if food was scarce, the men resumed their hunting, but today, after the early winter base camp is established, they begin trapping beaver, otter, mink, marten, and weasel. Daily trips are made from the base camp or from outlying temporary camps. When temporary trapping camps are used the men rarely remain away from base camp for more than 10 to 14 days at a time. Traps are usually set in a circuit of from 10 to 20 miles. The men work in pairs and alternate setting traps. Each man has his own traps and the furs taken are his own property. An attempt is made to examine the traps every weeks or so.

When in camp the men are busy constantly, manufacturing various items of equipment. Snowshoe frames are constructed during this period, swallow-tails in the late fall, and beaver-tails during the winter. Other items manufactured include toboggans, sleds, snow-shovels, skin stretchers, and axe handles. The men also tend the fish nets, often accompanied by their wives or older children.

Women engage in various tasks about the camp. The collection of firewood is very important, and an attempt is made to provide a reserve supply, especially during the winter. Wood is transported to camp on a sled or a toboggan. Women generally draw the sleds themselves, men employ dogs. After the logs are brought to camp, they are sawed into stove lengths,

split, and piled inside the passage to the lodge or in front. Women and children do most of this work.

Women collect the boughs for flooring. These are gathered in the immediate vicinity of camp and hauled in on sleds or toboggans. Other duties of the women include lacing snowshoes, making mittens and moccasins, mending, cooking, and preparing pelts. In addition to these regular tasks they hunt ptarmigan and spruce grouse and set a few traps in the neighbourhood of the camp. Hunting carried out by the women is of vital importance to the larder, especially when big game and fish are scarce and the men are concentrating on trapping.

Although the entire winter period is a time of intensified activity, the time of the early winter trapping is exceptionally strenuous. Everyone works from early morning until late evening. Outside work is limited by the number of daylight hours and occasionally by extremely low temperatures. The men rarely set traps or travel after dark.

The work routine continues until early January, when the mid-winter feast is held. Today this feast tends to be replaced by a Christmas feast. Shortly after Christmas the traders arrive by plane to buy fur.

In early January the traps are collected and preparations for moving begin. A shift is made to another section of the hunting territory that has not yet been exploited. Now more time is spent hunting big game, although trapping is resumed. The move is made with sleds and toboggans and may require a month, even though the distance does not exceed 30 miles. Intense cold and wind prevent extensive travel with small children. In addition it is necessary to stop early to establish camp, which task often consumes 4 hours at this time of the year. If there is much equipment, additional trips are required. Work is limited by the relatively few hours of daylight. There is little or no trapping, since the cold weather forces the animals to seek cover, where they are difficult to capture. At present, when money is available, the group or a family within the hunting group may charter a plane for the move, but the practice is rare.

With the departure from the early winter camp each family moves into a canvas tent for travelling and usually at base camp as well. When the new base camp is established, fish nets are placed under the ice and traps are set. For both sexes work is similar to that at the early winter camp. Hunting camps are established when caribou are sought, but few hunting groups today hunt caribou, since the animal is rare in the area. If possible, all the men co-operate in making the kill. If the kill is large, camp is moved into the vicinity and a communal lodge erected in which the meat is dried and the hides are processed. It is considered easier to move the entire camp than to transport the meat if large distances are involved. Furthermore, the communal lodge is considered best for drying meat in winter.

In early April an Easter feast is held and the group begins the return to the canoes. Failure to reach them before the spring thaw might prove disastrous. In March and especially in April it is necessary to travel early

in the morning before the crust on the snow softens, since at this time even snowshoes are of little value. Often camp is broken by 4 o'clock in the morning.

The period from the freezing to the thawing of the lakes (November to May) is the most difficult part of the year. During this period it is hard to secure the necessities of life. The large quantity of firewood required is obtained only by a great expenditure of labour and time. Hunting is hazardous because of climatic conditions, and game is often difficult to find. Fishing is curtailed. This is partly due to the fact that fish remain somewhat inactive in deep water, but in addition the ice is so thick that in February it sometimes takes nearly a whole day to set one net. Formerly the small amount of European food brought in by the group in the fall had been consumed by mid-winter. Even today some families have no flour by early spring. Illness during this period is particularly disruptive, since a husband curtails his hunting if his wife is ill, or ceases hunting if sickness strikes him.

During the later part of April the group returns to the vicinity of the early winter encampment to await the disappearance of snow and ice. Prior to the thaw the men aid the women by collecting sufficient wood and boughs for a period of several weeks. This is done because movement is difficult in melting snow. The snow conditions do not, however, prevent hunting and trapping. As soon as open water appears in the lakes and streams traps are set for muskrat and otter. Ducks, geese, and loons are hunted, and limited canoe travel is now possible.

During the early part of this period fishing is important. Two factors assure a good supply of fish: first, gill nets can now be set with a minimum of labour in the open water, and second, many species are moving into shallow water to spawn. At this season nets are examined about once a day. In April the hunting group may camp near good trout ponds and fish with set lines.

Outside activities increase with the additional daylight hours. The men often leave to go hunting and trapping by 5 o'clock in the morning and do not return until 8 or later in the evening, when they may continue to work indoors.

In May, when many ducks, geese, and loons are killed, a spring feast is held. The remaining bear meat and fat is cooked and served. (In 1808 McKenzie wrote that the Montagnais had a feast in spring in order to congratulate each other on their success during the past winter (McKenzie 1808, p. 416). The feast was apparently held after they had all gathered at the summer encampment. At Rupert's House this feast was a petition and thanksgiving to the supreme being (Cooper 1934, p. 228)).

Toward the end of May preparations are made to leave for the summer encampment. Canoes are repaired and paddles made. Winter equipment is stored on cache racks. When the ice disappears from the lakes and rivers the hunting group begins the return trip. They may wait until the water-level has lowered sufficiently so that any rapids encountered can be

negotiated easily. The trip is made in a minimum of time. Whereas 4 weeks are necessary in the fall, only 4 days are now needed if travel is down stream. Camp is struck early and made late. Personal comfort is forgotten in the general eagerness to reach the summer post. By the first part of June all hunting groups have, as a rule, gathered for the summer.

During the summer little work is done. The contrast with the isolation and strenuous activities of the winter is marked. Summer is the time of social affairs, with dances, marriages followed by feasts, and church services every day except Saturday. There is time now for conversation and gossip with relatives and friends.

A little hunting is done, especially for moose. Loons and ducks are taken when possible and a few rabbits are snared. Fishing is of major importance and each family sets one or more nets. Because of the large number of people at the summer encampment, about 500 in 1954, there is a heavy drain on the fish population. Nets may have to be set several miles from camp. They are examined almost every day. Much food is obtained from the trading companies during this period. Formerly birch bark was gathered during June for the manufacture of canoes and boxes.

Some of the men work as guides for fishing parties, in mining camps, and for the government. In addition to regular camp chores, women make gill nets, smoke moose hides, and make mittens and moccasins for sale to the trading companies. Toward the end of their stay at the summer encampment the men recanvas canoes and make paddles and axe handles. During the first part of August supplies are purchased and equipment is packed in preparation for the fall travel. By the middle of August a new cycle begins.

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THE INCUBATION PATCH OF WILD GEESE: ITS RECOGNITION AND SIGNIFICANCE

Harold C. Hanson*

THE incubation patch of birds consists of one or more areas of the skin of the breast and belly that become denuded of feathers and highly vascularized prior to incubation. Its function is to permit intimate contact of the body of the bird with the eggs, thereby increasing the efficiency of heat transfer. In its formation down feathers alone or both down and contour feathers may be lost. In passerine birds this feather loss is caused by a localized molt that results from hormonal action. (Bailey 1952).

Whereas it is common knowledge that the incubation patch in waterfowl is formed when the female plucks breast fathers for the nest, little attention appears to have been given to the details of its formation and subsequent history. The present observations on the incubation patch of wild geese, which were made at Perry River, District of Mackenzie, N.W.T., Akimiski Island, N.W.T. (in James Bay), in the Sutton River area, Ontario (south of Hudson Bay), and at the Horseshoe Lake Wildlife Refuge, Alexander County, Illinois, have suggested that the patch, particularly in its subsequent refeathered state, which heretofore has not been generally recognized, may have significance and usefulness in population studies.

The following species and subspecies of geese have been studied (nomenclature after Delacour 1954): white-fronted goose *(Anser albifrons frontalis)*, blue-lesser snow goose *(Anser caerulescens caerulescens)*, Ross's goose *(Anser rossii)*, emperor goose *(Anser canagicus)*, Todd's Canada goose *(Branta canadensis interior)*, Moffitt's Canada goose *(Branta canadensis moffitti)*, lesser Canada goose *(Branta canadensis parvipes)*, cackling Canada goose *(Branta canadensis minima)*, and black brant *(Branta bernicla orientalis)*.

Acknowledgements

Studies in the Perry River region in 1949 were aided by a contract with the Office of Naval Research, U.S. Department of the Navy, and the Arctic Institute of North America (Hanson, Queneau, and Scott 1956). Field studies of Canada geese on Akimiski Island in 1958/9 were also made possible by a grant from the Arctic Institute. The writer is deeply appreciative of the invaluable support the Institute has given his studies of

* Illinois Natural History Survey, Urbana, Ill., U.S.A.

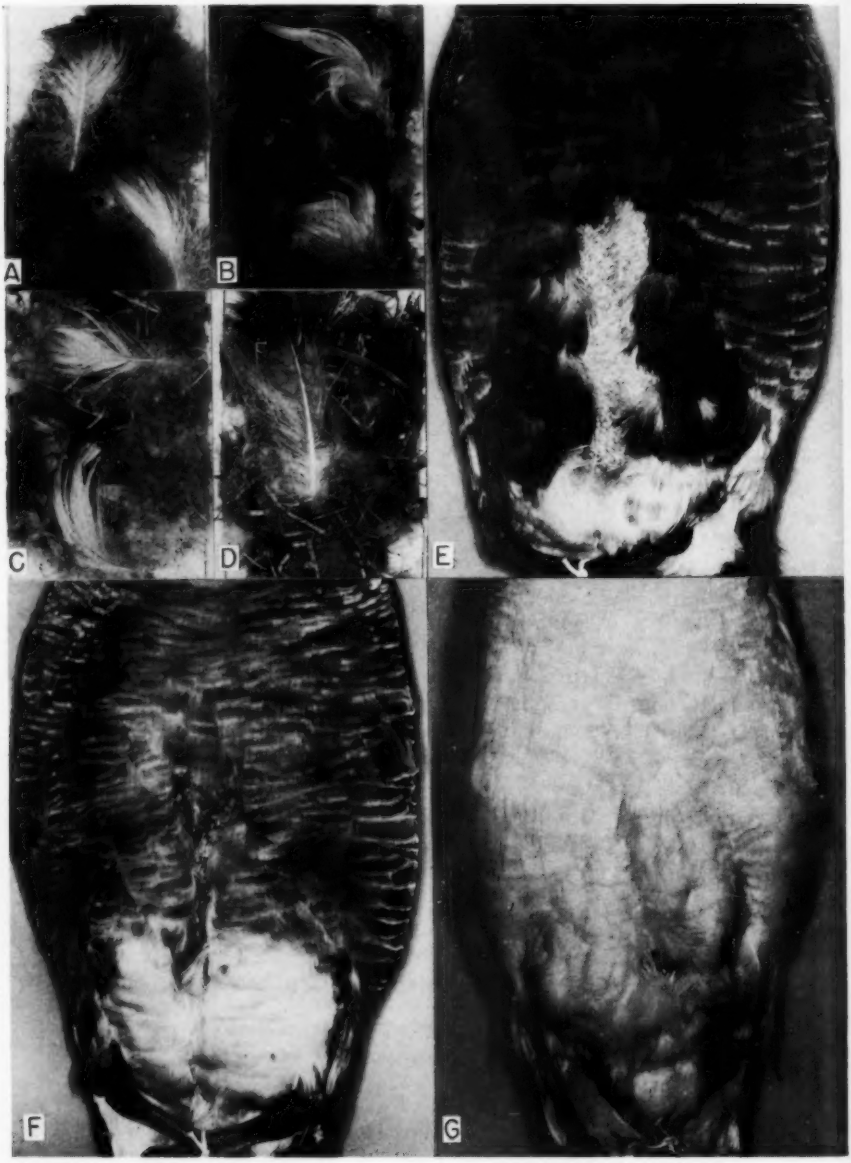

Fig. 1. A-D, Down and breast feathers from nests of: **(A)** black brant, **(B)** lesser Canada goose; **(C)** Ross's goose, **(D)** white-fronted goose. **E-G,** Undersides of adult female geese: **(E)** black brant at an early stage of incubation, **(F)** lesser Canada goose collected with newly hatched young, **(G)** Ross's goose collected with young 4 to 5 days old. All specimens from Perry River.

wild geese. For personal encouragement in this regard the writer is grateful to Admiral L. O. Colbert, Dr. Walter Wood, and Mr. Joseph Flakne of the Institute.

Field work in the northern Ontario region was greatly aided by the air transport provided by the Ontario Department of Lands and Forests. For this and many other courtesies the writer is indebted to Dr. W. J. K. Harkness, Dr. C. H. D. Clarke, Harry Lumsden, Lou Ringham, Frederick Hall, and James Taylor. For granting permission to carry out studies in the Akimiski Island Bird Sanctuary the kindness of Mr. Winston Mair, Chief, Canadian Wildlife Service, is gratefully acknowledged. The loan of skins from the Chicago Natural History Museum was facilitated by Mr. Emmett R. Blake. Photographs of these skins and of down samples are by William E. Clark, Survey photographer, who also assisted in the preparation of the plates. The co-operation of refuge personnel of the Illinois Department of Conservation was, as always, important to the success of winter studies at Horseshoe Lake.

The present paper is one of a series that will form the base of a definite report on the Canada goose. Progress toward attainment of this objective has greatly benefited by the constructive advice and support of Dr. Thomas G. Scott, Head of the Section of Wildlife Research.

Previous studies

Brandt (1943, p. 261) noted that during the breeding season Pacific eider ducks *(Somateria v-nigra)* possess two types of down; one, the *permanent* down, and a second, the *nuptial* down, the latter being coloured differently from the first and more readily pulled out. It is clear from the writings of Brandt (1943, p. 261) and Witherby *et al.* (1943) and supported by the writer's experience that geese pluck and use both down and contour feathers in the nest (Figs. 1A, B, C, and D). The amount of down in a nest of a duck is generally regarded as an indication as to whether the full complement of eggs has been laid, since the amount of down deposited increases with the progress of egg laying. Hochbaum (1944) has stated that in duck nests "down seldom appears in the nest before the third or fourth egg is laid; the nest may not be completely lined with down until it holds most of the clutch". Conversely, Brandt (1943) reported that geese do not deposit down in the nest in quantity as early in the incubation period as do ducks, and that important differences exist between species (see pp. 275, 325, 326, 330, and 333). The cackling Canada goose does not add much down to its nest, whereas the emperor goose deposits large amounts in the nest just before hatching of the eggs. Cottam *et al.* (1944, p. 51) state that "probably three times as much down is used [in the nest] by the brant as by the snow goose". Kossack (1950), reporting on semi-captive Canada geese near Barrington, Illinois (most individuals appear to have been *Branta canadensis moffitti),* wrote: "small quantities of down generally appear when the third egg is laid; the quantity of down generally increasing until incubation is started".

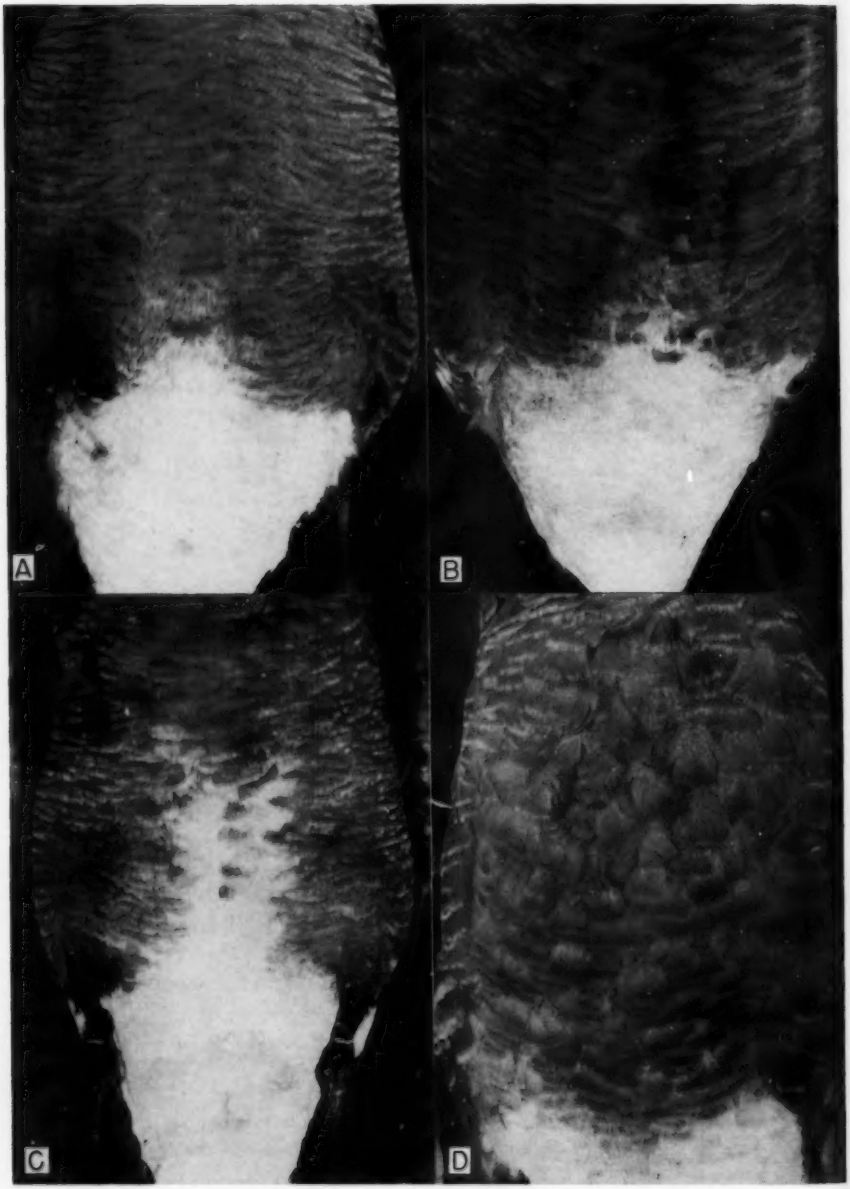

Fig. 2. A-C, Undersides of adult female Canada geese during the flightless period, **D.** the underside of an adult male during the body molt, Akimiski Island, N.W.T.

Phenology, characteristics, and occurrence of the incubation patch in breeding geese

The timing of the appearance of the incubation patch in geese and its refeathering can be roughly delineated by data from a variety of species and subspecies. The denuded area of the breast is most obvious during the incubation period. Two female black brant collected at Perry River during the early stages of incubation both possessed a large brood patch (Fig. 1E). Neither the sexually immature yearlings nor the adult males (which do not incubate the eggs) have an incubation patch.

As a female goose plucks her breast chiefly as the clutch nears completion and during the early stages of incubation, the denuded areas have begun to be refeathered by the time the young have hatched. The feathers of the incubation patch of a lesser Canada goose collected at Perry River with young only 1 or 2 days old had barely begun to grow (Fig. 1F); a Ross's goose collected at Perry River with a brood of five, estimated to be about 5 days of age, had its incubation patch partly refeathered (Fig. 1G). In Canada geese *(B. c. interior)* studied on Akimiski Island in 1958, all adult females had the patch area completely and evenly refeathered by the time their young were 2½ to 3 weeks old (Figs. 2A, B, and C). It was strikingly apparent, however, *that the area of feather replacement of these geese could be readily distinguished from the remainder of the breast because the newly replaced feathers were either more brightly coloured than the surrounding faded brownish breast feathers or were white or partly white.* In some only the edges of the new feathers of the incubation patch were white, thereby imparting a frosted appearance to the plumage. However, because the post-nuptial molt of the body feathers occurs shortly after the incubation patch has been refeathered incubation remains evident only if the new feathers are all or partly white.

During the spring migration at Hawley Lake (Ontario) in May 1959 the writer was able to distinguish readily three age classes of Canada geese: immatures (geese nearly 1 year old); yearlings (geese nearly 2 years old), and old adults (geese about 3 or more years old). However, during the flightless period on Akimiski Island in July and early August 1958, only two ages classes of geese could be distinguished: the immatures of the previous winter (classified as yearlings during their second summer of life) and all older geese.

Two-year-old females that have nested cannot be distinguished during their third summer of life from older females for the reason that the bursa of Fabricius is apparently absorbed rapidly during the early stages of incubation. The opening to the bursa of a 2-year-old female shot on June 3, 1959 was greatly reduced in size and its walls were membranous in character rather than glandular.

On the other hand, female geese during their second summer on the breeding grounds could be distinguished from older females by the possession of one or more pairs of badly abraded outer tail feathers, an open

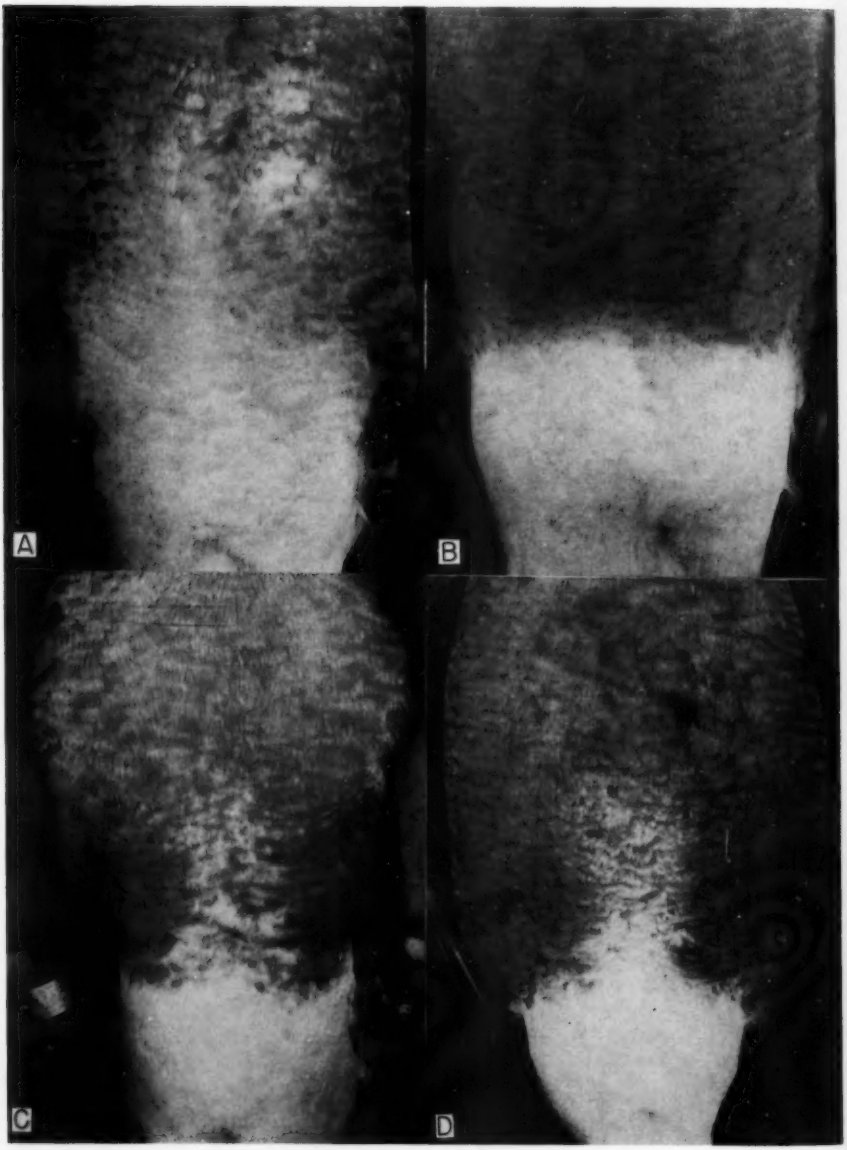

Fig. 3. Undersides of **(A)** an immature male, **(B)** yearling female, and **(C and D)** adult female Canada geese.

bursa of Fabricius or, even more positively, by a closed oviduct. The latter remains closed in yearling female geese throughout the second winter (Hanson 1949).

Evidence of a former incubation patch in wintering geese

The evidence in the form of different refeathering indicating a former incubation patch in Canada geese *(B. c. interior)* wintering at Horseshoe Lake, Illinois, was studied in late 1958. Immature geese are highly variable in the fall (Fig. 3A), frequently still undergoing the post-juvenal molt of their breast feathers, but this age class was readily identified by notched tail feathers, as well as by cloacal and other characteristics. Sexually immature yearling males and females, as well as adult males were eliminated from consideration by cloacal characters (Hanson 1949a). In these latter age-sex classes there is a fairly sharp line of demarcation, both in summer and winter, between the white feathers of the belly area and the grayish or brownish feathers of the breast (Fig. 3B).

Of 87 adult female geese studied that were 2½ or more years old and that had presumably nested the previous spring only 28 (32 per cent) possessed a feather patch on the underside that indicated a former incubation patch. In these individuals the patch feathers were either (1) all white (Figs. 3C and D), (2) some all white or with white tips and some normal (Figs. 4A and B), or (3) a mixture of light and dark (Figs. 4C, D, and E). These findings were in agreement with conclusions suggested by examination of birds on the breeding grounds: namely that in those individuals in which the colour of the new feathers of the patch area is the usual gray, the feathers of the former incubation patch cannot be distinguished from the rest of the feathers of the underparts after the latter have been replaced in late summer during the post-nuptial molt.

These observations give rise to questions that can at present not be fully answered. Are the feathers of the former incubation patch lost again at the time of the post-nuptial body moult? Skins collected in 1959 in late July, when the post-nuptial moult of the contour feathers was well under way, clearly provide evidence that they are not. The underparts of these skins show that replacement is taking place everywhere on the ventral surface of the body except on the patch area. It was notable that replacement was also taking place along the mid-line of the patch area, the strip over the keel of the breastbone that is not totally plucked when the patch area is denuded. The fact that patches marked by white feathers persist into the winter period and are not replaced by gray feathers during the post-nuptial moult is further evidence in this regard. Is the incubation patch of moulting geese a completely reliable criterion that the individual had nested in a given season? Experience gained by the writer with geese held in w · cages and from observations of non-breeding, sexually mature semi would indicate that it is. No localized breast moult or different hered area has been observed in these females although they

were handled during the spring and summer periods for several years in conjunction with physiological studies of the moult.

It probably can be assumed that females of most species of geese that have nested will show plumage evidence of a former incubation patch until some time during the flightless period, although in white geese or white-bellied geese (blue goose-snow goose crosses), some difficulty may be experienced in detecting the patch areas, although the amount of wear exhibited by the edges of the contour feathers should be indicative. To investigate whether geese other than Canada geese may show evidence of a former incubation patch in winter, skins at the Chicago Natural History Museum were examined. Species of North American geese that were represented by adult females contained in their series specimens that showed plumage differences associated with former incubation patches (Figs. 4F-J).

Discussion

The genesis of white feathers or partly white feathers in areas of former incubation patches of adult females, which in yearlings and adult males are normally gray or brown, is of particular interest. It was recorded earlier (Hanson 1949b) that white spotting in geese increases with age and occurs more frequently on the underside of the wings in old females. Physical injury to the follicle resulting from plucking would, at the outset, appear to be one possible explanation. For example, Hutt (1949, p. 182) stated that in domestic chickens "white feathers are occasionally found in birds that once had only black or coloured plumage. They may develop spontaneously, be caused by injury, or be induced by excessive doses of thyroxine."

Although an enlarged thyroid gland alone is not necessarily indicative of an increased rate of secretion, the fact that they tend to increase in size during the flightless period (Hanson 1958 and unpublished), is reason to suspect that thyroxine may play a role in the development of white spotting in the incubation patch.

Bailey (1952) has cited the report of an immature black-headed gull *(Larus ridibundus)* that developed incubation patches. However, the fact that the patch in waterfowl is dependent on plucking and that the hormonal level must be such that it induces this behaviour trait would seem to preclude the likelihood of a female developing an incubation patch without actually having laid eggs. In this regard it is to be noted that in waterfowl both the contour feathers and the down have the added important function of providing the eggs with insulation; in most passerine birds the lost feathers serve no further function. If the feathers of the patch area in waterfowl were molted promiscuously merely as a result of a higher hormonal level at the time of egg laying, they would not be available for placement in the nest. Instead, it would seem that there is a direct relationship between the plucking of the patch feathers subsequent to the initiation

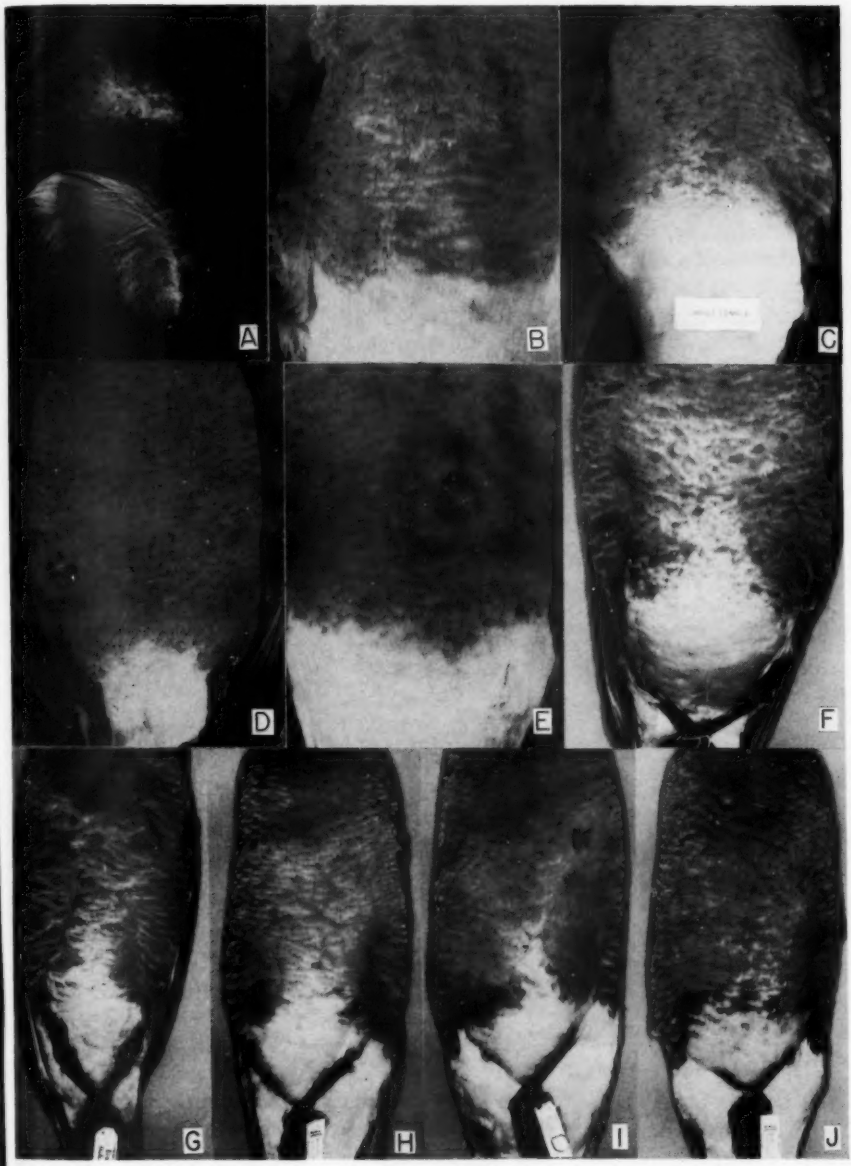

Fig. 4. **(A)** Breast and down feathers from an adult female Canada goose in late fall, **(B-E)** undersides of adult females from Horseshoe Lake, Illinois, **(F)** underside of a lesser Canada goose from British Columbia, **(G-J)** undersides of cackling geese collected in California.

of egg laying and the production of an incubation patch. In fact, a high dependence of the plucking behaviour on complete development of the sexual (hormonal) cycle is suggested by the fact that down is placed in the nest only in the later part of the egg laying period.

Evidence for this relationship was found in studies of nesting Canada geese along the Sutton River in the spring of 1959. A 2-year-old female nesting for the first time had a clutch of only three eggs and a small incubating patch; an old female that had laid a clutch of seven eggs (the largest found), had the most extensive incubation patch of eight nesting females collected (Figs. 5A and B respectively). It is presumed that prolactin is the hormone chiefly responsible for the development of feather plucking in geese nearing the end of an egg laying cycle.

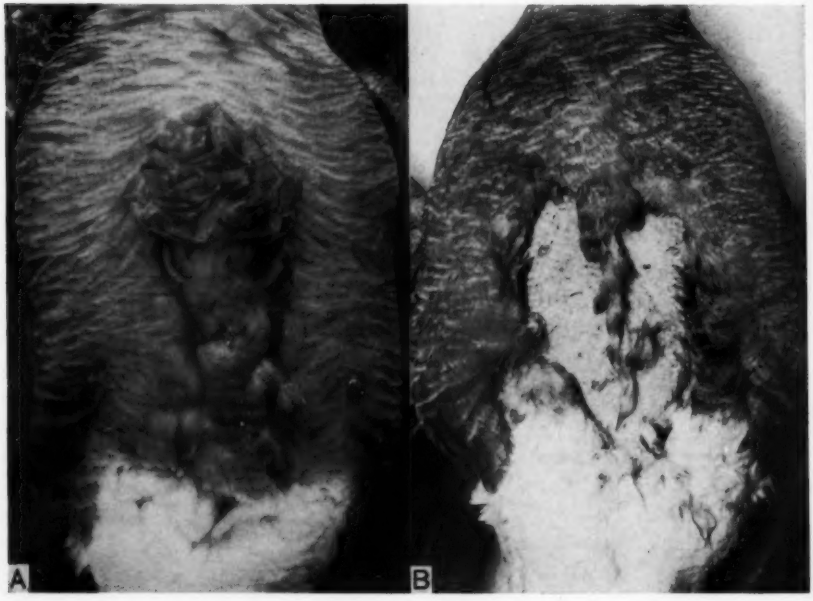

Fig. 5. Incubation patches of Canada geese during early stages of incubation. **(A)** a 2-year-old female on June 3, 1959 that had a clutch of three eggs, **(B)** an old female on May 28, 1959 that had a clutch of seven eggs.

Observations made to date on the incubation patch in geese suggest that it may have considerable use in population studies of these birds on the breeding grounds. From the findings at hand it is evident that in Canada geese (1) the incubation patch can be used throughout the flightless period as a convenient aid, in addition to cloacal characters, in distinguishing older females from yearling females and adult females from adult males, (2) that breeding in the wild often begins at 2 years of age instead

of 3, a possibility advanced earlier by Hanson and Smith (1950), because an apparently 2-year-old component of the population was not separable from older geese, either by cloacal or plumage criteria. Thus recognition of the refeathered former incubation patch during the flightless period should aid in productivity studies, as by its presence or absence the investigator is able to separate females that have laid eggs from those that have not.

Because only a relatively small percentage (32 per cent) of the adult females that may have nested during the breeding season could be recognized in winter (those with white spotted or mottled patch areas), successful diagnosis of recent breeding in females must lie in studies of molting females on the breeding grounds. In temperate regions it may be assumed that nearly 100 per cent of the sexually mature females lay eggs; in the High Arctic, on the other hand, the onset of break-up may be so late and the spring-summer period so cold that a significant part of the bird population of the region may not nest in some years (Marshall 1952). In such years the plumage characteristics of females caught in drive traps should be a fairly accurate measure of the extent of non-breeding that may have occurred. However, care would have to be taken in examining catches to distinguish adult geese from yearlings by cloacal characters (Hanson 1949a).

The proportion of geese with incubation patches plus age-sex ratios of the previous winter appear to have usefulness in making predictions of the size of the fall populations of Canada geese. During fall and winter six age-sex classes of geese can be distinguished: male and female immatures, yearlings, and adults. Separation of adult females that have nested from those that have not by means of the incubation patch now makes it possible to separate a seventh age-sex class in Canada goose populations. In summer, however, only five age-sex categories can usually be distinguished because most yearlings of the previous summer and winter are indistinguishable from older adults. In the past the size of fall populations of Canada geese of the Mississippi flyway has been successfully predicted a year in advance on the basis of age-sex ratios and assuming an average brood size of three for all adult females (Hanson and Smith 1949). A more refined appraisal of the kill of these geese by the Indians (Hanson and Currie 1957) has improved the accuracy of such forecasts (Donald Smith and Rossalius Hanson, U.S. Bureau of Sport Fisheries and Wildlife, personal communication). It is therefore possible that it also will be advantageous to ascertain what percentage of the adult females nested in a given year. Since it may not be feasible to do this every year because of the remoteness and difficult nature of the breeding grounds, a study over a period of several years would be desirable in order to obtain an average value. For threatened populations and those nesting in the High Arctic a study of the flightless females on the breeding grounds would be especially important.

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SOME PALAEOMAGNETIC MEASUREMENTS IN ANTARCTICA

G. Turnbull*

Introduction

THE mean direction of magnetization of rock formations of a particular age may be taken to represent the mean geomagnetic field at the time they were formed (Creer *et al.* 1957). There are strong theoretical reasons for believing that the mean geomagnetic field, obtained by averaging over many thousands of years, closely approximates to that of a geocentric dipole along the axis of rotation (Runcorn 1954). Thus the sampling of a series of sediments of more than a few feet in thickness, or a succession of lava flows, enables the ancient position of the rocks relative to the axis of rotation of the earth to be determined.

In recent years palaeomagnetic methods have provided information from most of the major land masses of the earth on the respective orientations of the geomagnetic field — from which may be deduced the position of the pole with respect to those land masses — during the geological past. It seems probable, if the above premises are correct, that both polar wandering and continental drift have occurred, the latter more particularly between southern continents.

The activity engendered by the International Geophysical Year 1957-8 provided an opportunity to obtain suitable rock specimens from the antarctic continent, and the author was able to visit two localities in Victoria Land. At Cape Hallett (72°S., 171°E.) the prominent Cenozoic volcanics were sampled, but the Palaeozoic sediments of the Robertson Bay group, quite highly metamorphosed in this region, were rejected as unlikely to provide reliable data on the ancient magnetic field. In the Ferrar Glacier region (78°S., 161°E.), samples were collected from the late Palaeozoic/early Mesozoic Beacon sandstone, and from the extensive Mesozoic dolerite sills intrusive within the sandstone series.

The remanent magnetizations of the rocks collected were measured at King's College, University of Durham. A sensitive astatic magnetometer was employed to measure the weaker magnetization of the sedimentary rocks and a simpler instrument was used for the more strongly magnetized igneous specimens (Collinson *et al.* 1957).

Mean directions of magnetization and corresponding pole positions were calculated, and the 95 per cent level of confidence estimated in the usual way (Fisher 1953, Creer *et al.* 1957).

* Physics Department, King's College, Durham University, Newcastle upon Tyne.

Acknowledgements

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Results

Cenozoic volcanics of Cape Hallett (72°S., 171°E.)

Twenty-three oriented samples were taken from the Cenozoic lava flows occurring in the neighbourhood of the United States/New Zealand IGY station at Cape Hallett. Twenty-one of these were magnetized in the reverse sense, that is, with a magnetization essentially antiparallel to the present geomagnetic field (Table 1, Fig. 1). This in itself suggests that the magnetization is stable.

The oval of confidence about the ancient pole position just fails to include the present geographic pole. It is probable that some error would

Table 1. Results of measurements.

Samples		Mean direction of magnetization				M x 10^4 (c.g.s. units)	Pole position			
		D	I	α	K		Lat.	Long.	dψ	dχ
Cenozoic volcanics of Cape Hallett 72°S., 171°E.		S.28°W.	-80°	4.2°	48	44	81°S.	94°E.	7.8°	8.1°
Dolerite sills (Mesozoic) Ferrar Glacier 78°S., 161°E.	Site 1	S.85°W.	-79°	7.6°	54	10				
	Site 2	S.68°W.	-77°	4.9°	50	20				
	Site 3	S.82°W.	-76°	4.6°	92	13				
	Site 4	S.73°W.	-72°	6.8°	67	11				
	Site 5	S.77°W.	-75°	8.7°	50	20				
	Mean of all samples	S.75°W.	-76°	2.7°	52	15	58°S.	142°W.	4.8°	5.1°
Beacon sandstone (Red band) (Late Palaeozoic/ early Mesozoic) Ferrar Glacier 78°S., 161°E.	Site 1	S.53°W.	-77°	9.6°	39	2.5				
	Site 2	S.72°W.	-67°	7.6°	54	1.2				
	Site 3	S.63°W.	-76°	5.9°	66	1.5				
	Mean of all samples	S.64°W.	-74°	4.0°	44	1.6	53°S.	151°W.	6.5°	7.2°

D — declination of the magnetization vector
I — inclination of the magnetization vector (positive below the horizontal plane)
α — semi-angle of the 95-per-cent cone of confidence
K — precision (Fisher 1953)
M — logarithmic mean intensity of magnetization (magnetic moment per unit volume)
ψ, χ — semi-axes of the oval of confidence about the pole position at the 95-percent probability level (Creer *et al.* 1957)

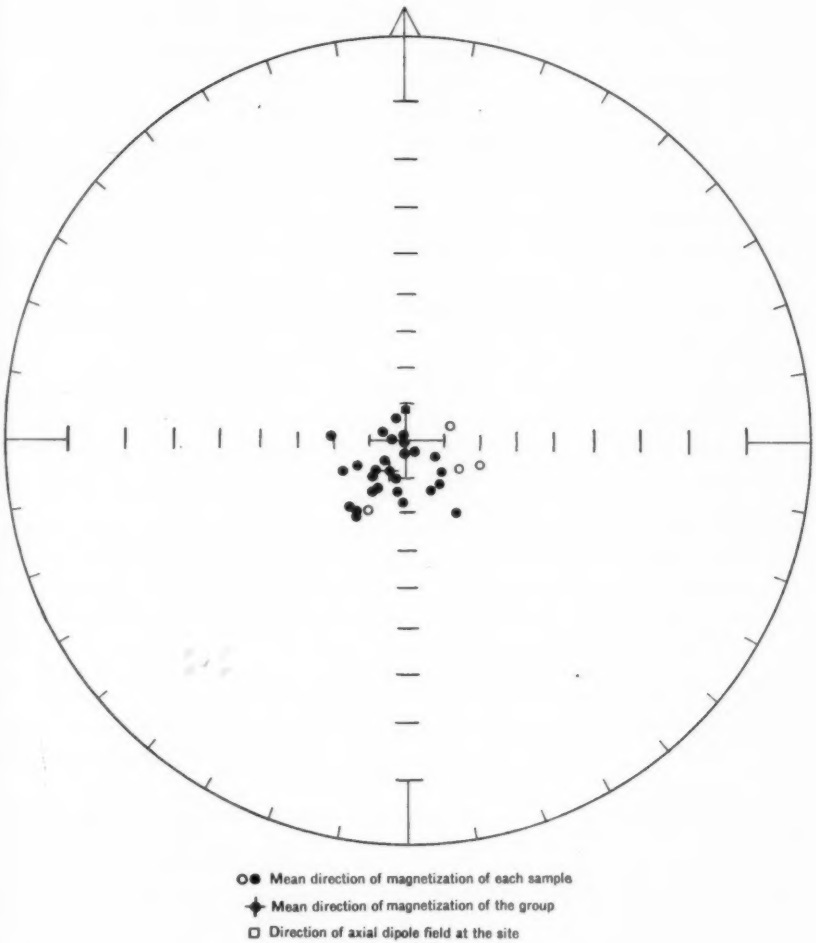
Mean direction of magnetization of each sample
Mean direction of magnetization of the group
Direction of axial dipole field at the site

Fig. 1. Cenozoic volcanics of Cape Hallett — Direction of magnetization. The polar stereographic projection is used. Full symbols represent directions inclined downward (+ve), open symbols directions inclined upward, projected respectively on the lower and upper hemisphere.

be introduced by imperfect averaging of the secular variation, and since the field relations were insufficiently clear to rule out entirely the possiblity of post-formational movements, this difference must be considered as of doubtful significance. The result agrees with earlier palaeomagnetic evidence, which shows that in both hemispheres the average geomagnetic poles have been aligned along the present axis of rotation for the last 20 million years (Hospers 1955, Irving and Green 1957).

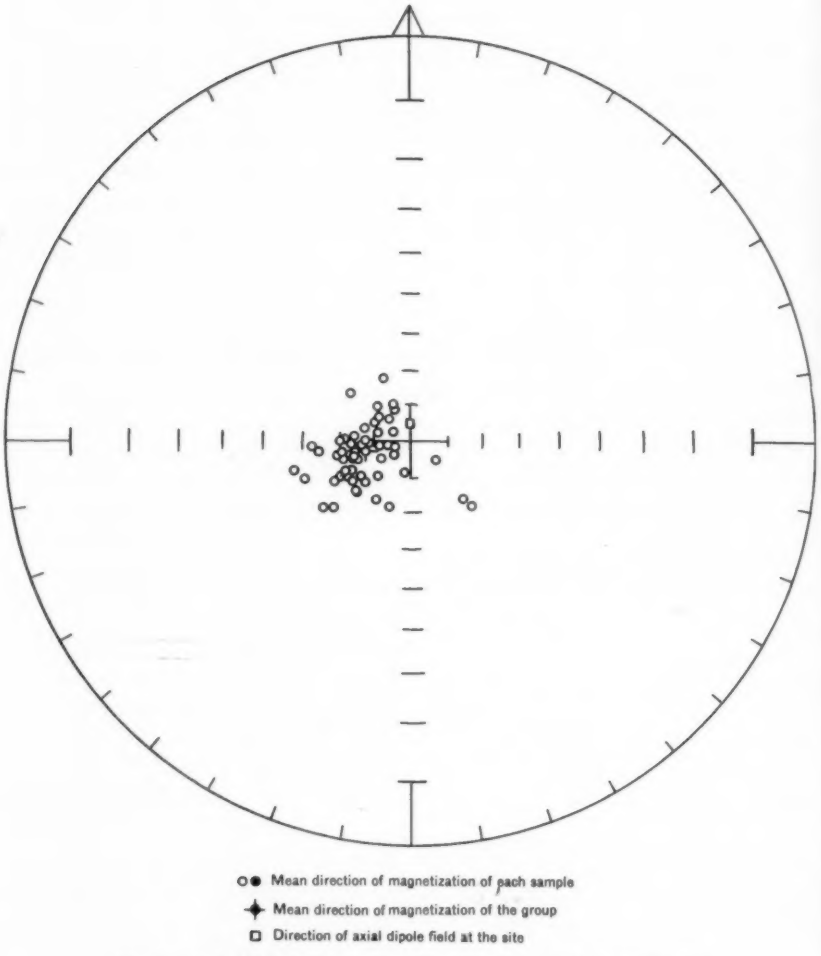
Mean direction of magnetization of each sample
Mean direction of magnetization of the group
Direction of axial dipole field at the site

Fig. 2. Dolerite sills of Victoria Land — Direction of magnetization.

The two remaining samples were normally magnetized, with the same polarity as the present field of the earth, but in both instances field relations were suggestive of non-contemporaneity with the larger group. To make sure that the "normal" magnetization was due to a stable thermo-remanent magnetization, rather than to a soft isothermal component of magnetization associated with the present field, the two specimens were subjected to demagnetization in an alternating field of 500 gauss (Creer 1958).

A reduction in intensity of magnetization to 20 to 30 per cent of the initial value was effected, but the shortened magnetization vector maintained the same polarity and essentially the same orientation.

Dolerite sills of Victoria Land (Ferrar Glacier, 78°S., 161°E.)

The uniformly horizontal sandstone typical of Victoria Land is intruded by dykes and vast sills of dolerite, believed to be of Jurassic or early Cretaceous age. Individual sills are usually some hundreds of feet thick, the aggregate thickness being over 4,000 feet (Debenham 1921).

Fifty-seven samples were collected from five sites near the upper Ferrar Glacier. Good exposures were found in dry valleys, cut during a period of more intensive glaciation and contingent upon the main glacier. Sites 2, 3, and 4 fell within a radius of about 5 miles, sites 1 and 5 were about 10 miles on either side of this central position.

All specimens were magnetized normally, with a mean direction rather close to the present field. (Table 1, Fig. 2). Whereas the comparatively high values of the precision K (Fisher 1953) suggest a significant result, it is not immediately apparent whether a less stable "soft" component of magnetization aligned in the not wholly dissimilar direction of the geocentric dipole field is present. Stability tests dependent upon field relations as described by Graham (1949) were precluded by the uniformly horizontal nature of the strata. As a laboratory test a selected number of specimens were subjected to demagnetization in an alternating field of 500 gauss. A change in mean direction of magnetization of less than 3 degrees of arc was effected but the mean intensity of magnetization was reduced to 40 per cent of its initial value. It may be inferred that any isothermal component present is negligible in comparison with the thermo-remnant magnetization, so that the result obtained is representative of the ancient field.

A single dolerite specimen from the Queen Maud Range, at 83°S., 30°W., some 1200 miles distant from the Ferrar Glacier site, was reversely magnetized, with a direction

$$D = \text{S. } 31°\text{W.}, \quad I = +67°$$

On the basis of a magnetic pole at 58°S., 141°W., the expected direction of reversed magnetization at this site would be S. 60°W., + 71°, some 12 degrees of arc from the experimental result. The probability that a single direction differs from the mean by an angle of more than ψ is given by the formula

$$\text{Prob.}\ (\psi > \psi o) = \text{Exp.} - K(1 - \cos\psi) \qquad \text{(Watson and Irving 1957)}$$

If the value of the precision observed on the Ferrar Glacier collection (K = 52) is typical, a probability of about 32 per cent is implied. It may be concluded that this isolated observation is not inconsistent with the postulated position of the ancient pole.

Beacon sandstone series (Ferrar Glacier, 78°S., 161°E.)

A thickness of some 5,000 feet of uniformly horizontal sediments, assigned to the period Devonian — Triassic, overlies the basal complex in the McMurdo Sound region (Debenham 1921). The typical facies is a pale sandstone or quartzite, conspicuously lacking in the iron compounds upon which palaeomagnetic investigations depend. A few samples of this type were collected,

but in the main were too weakly magnetized for significant measurement. Exceptions were two quartzite specimens, baked by adjoining masses of dolerite. Their direction of magnetization agreed closely with that of the dolerites, as would be expected of a thermo-remanent magnetization acquired by reheating in the contemporary field.

A 40-foot thick band of an argillaceous sandstone, mottled red and green, and interlaced with narrow vertical bands of coarser pale sandstone, similar to the overlying strata and suggestive of root cavities, was found in the upper part of the sequence.

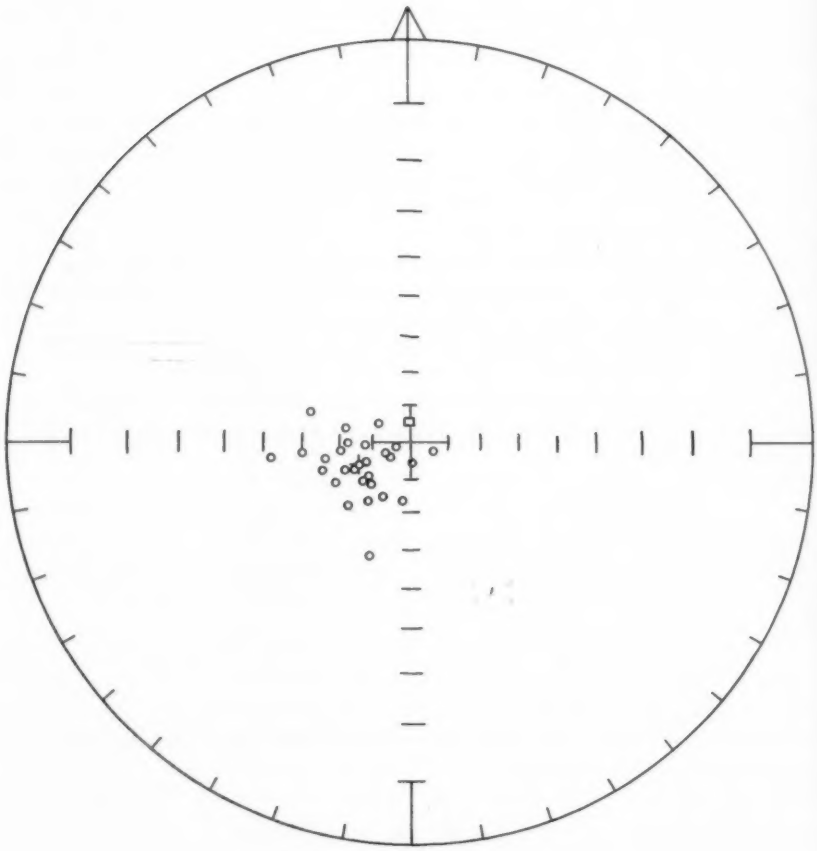
Mean direction of magnetization of each sample
Mean direction of magnetization of the group
Direction of axial dipole field at the site

Fig. 3. Red band from the Beacon sandstone — Direction of magnetization.

It will be seen (Table 1 and Fig. 3) that the mean magnetization differs from that of the indubitably younger dolerites by only about 4 degrees, an amount closely comparable with the inherent uncertainties of the method. It seems probable that the large intrusive masses nearby have caused sufficient heating to impose a component of partial thermo-remanent magnetization aligned with the ambient field at the time of intrusion. In support of this view is the scatter of the mean directions of magnetization obtained from the three sites. Site 2, which shows a mean direction of magnetization significantly different from that of the dolerites, was separated by no less than 500 feet of sandstone from the over- and under-lying igneous rocks. At sites 1 and 3 the thermal insulation was not quite so substantial. It must be concluded, therefore, that this magnetization is not an original one, and is significant only in that it lends support to the result obtained for the dolerite formation.

Conclusions

Uncertainties in geological age and — for the Cape Hallett lavas — of the sampling procedure, preclude any precise statements. However, some general conclusions may be drawn.

Here, as elsewhere, reversed directions of magnetization occur and may be interpreted as representative of reversals of the main magnetic field of the earth. Cenozoic rocks appear to have been magnetized in a mean field not essentially different from that of a geocentric dipole aligned with the present axis.

Older rocks are magnetized in a direction significantly different from that of the present mean magnetic field. This may be interpreted as evidence of polar wandering, implying a polar movement of some 30 degrees since the later part of the Mesozoic era. The data are perhaps too sparse to admit of a discussion of continental drift.

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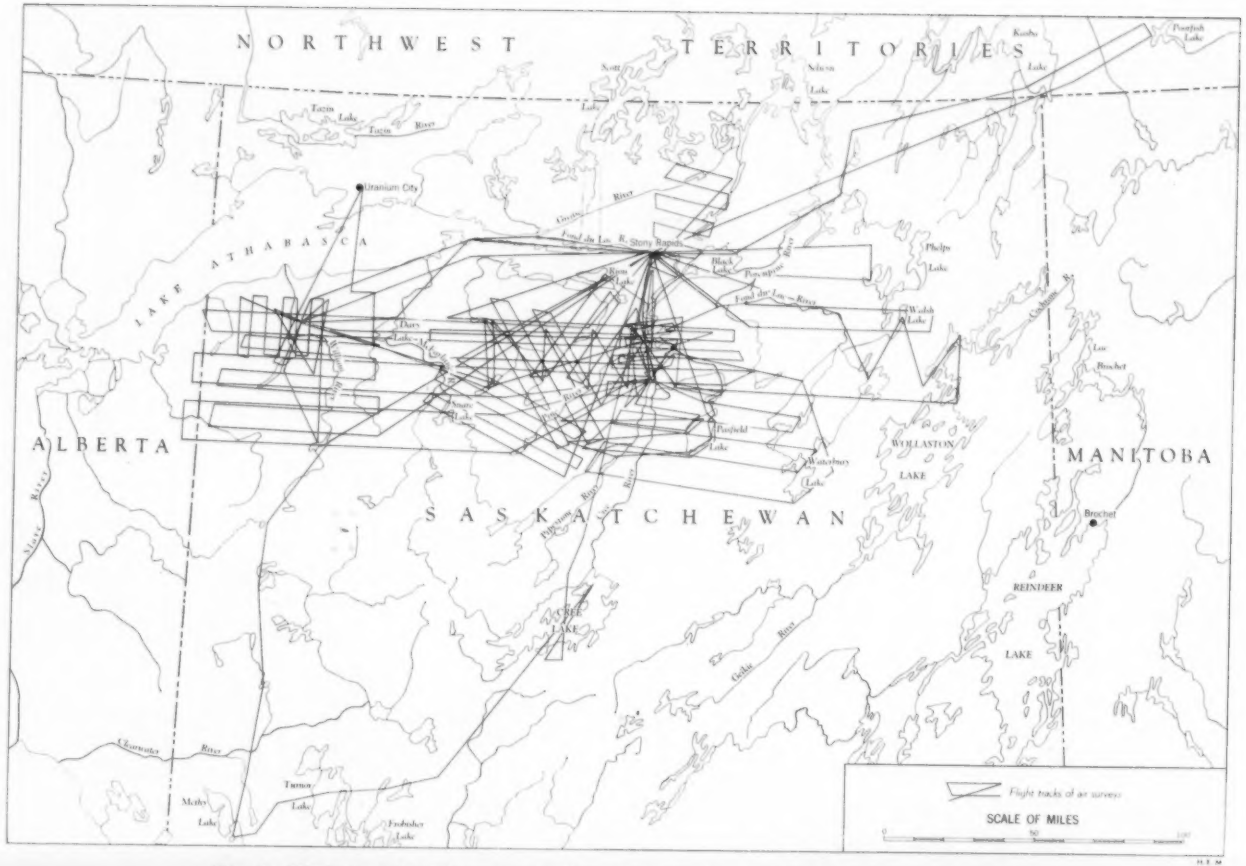

Fig. 1. Northern Saskatchewan and adjacent region, showing flight tracks of air surveys.

SNOW AS A FACTOR IN THE WINTER ECOLOGY OF THE BARREN GROUND CARIBOU

(*Rangifer arcticus*)

William O. Pruitt, Jr.*

ONE of the truisms of biology is that an animal cannot be considered apart from its environment. Yet in the brief history of northern biological research and especially in wildlife management this truism and its implications have frequently been forgotten in the haste to apply techniques used by biologists and wildlife managers in temperate zones. Too few biologists and wildlife managers have been cognizant of the fundamental ecological differences between the regions where the snow cover is permanent in winter and those where the snow cover is intermittent or lacking.

In the Subarctic many aspects of the animals' environment have an ecological effect quite different from that of the same aspects in the tempera‡e zone. For example, it is widely known that deep snow or icing conditions seriously affect whitetail deer populations, but deer are subject to nival factors for only a short period of the year. In the Arctic and Subarctic the Barren Ground caribou encounters snow as an integral part of its environment for at least 8 months of the year. Yet subarctic snow is one of the least understood of natural phenomena and the ecological effects of a permanent winter snow cover have been virtually ignored in North America. Only a few northern biologists have fully understood the ecological importance of the arctic and subarctic snow cover. Possibly the first to bring this to the attention of biologists working only in the temperate zone were the naturalists Seton (1909) and Dugmore (1913). Others who have contributed substantially to our understanding of the ecological importance of snow have been Formozov (1946, 1948) and Nasimovich (1955) in the USSR, Vibe (1954, 1958) in Greenland, and Siivonen (1952, 1956) in Finland. A number of earlier Russian workers are cited by Formosov and Nasimovich. Murie (1935) noted the importance of snow in the migration and seasonal distribution of Alaska caribou, which are essentially mountain animals. Grinnell (1924) reproduced a letter dated November 17, 1846 from Thomas Lincoln of Dannysville, Maine to John James Audubon in which the nival environment of the woodland caribou *(Rangifer caribou)* was outlined in detail. Edwards and Ritcey (1956) discussed the effects of snow depth on the altitudinal migration of moose *(Alces alces)* in British Columbia and Edwards (1956) correlated snow depths and trends in ungulate populations.

* Present address: Box 282, College, Alaska, U.S.A.

Fig. 1. Northern Saskatchewan and adjacent region, showing flight tracks of air surveys.

Description of the region

The study was made during the winter 1957-8. The region in which the snow cover was studied consisted of a large part of the northern quarter of the Province of Saskatchewan, a small part of the southeastern part of the District of Mackenzie, and a small part of the southwestern part of the District of Keewatin, N.W.T. (Fig. 1). The extensive survey included the region from near the mouth of William River on the south shore of Lake Athabaska east-northeastward to the vicinity of Poorfish Lake, N.W.T., thence south- and southwest-ward to the vicinity of Walsh, Cree, Frobisher, Turnor, and Methy (Lac la Loch) lakes, Saskatchewan. The extensive snow survey also included, for comparative purposes, a transect beyond the limit of trees into the tundra from the vicinity of Kasba Lake to Poorfish Lake, N.W.T. Intensive observations were made in the vicinity of camps situated at (a) 58°37′N., 105°50′W.; (b) 58°49′N., 105°52′W.; (c) 58°53′N., 109°08′W.; and (d) 58°23′N., 105°51′W. Observations on spring movements of caribou were made at 59°15′N., 106°14′W. and in the vicinity of the village of Stony Rapids, Sask. (59°15′N., 105°50′W).

An area of this size exhibits a wide variation in topography, vegetation, use by caribou, and history of use by man. On the basis of topography and geology two broad divisions can be recognized (Alcock 1936): (1) the region north and east of Lake Athabaska-Fond du Lac River-Black Lake, which has a great deal of exposed bedrock, is very rugged and has many elongated and deep lakes with steep, frequently precipitous banks. The country rock of this region is composed mainly of granites, gneisses, limestones, and volcanic lavas. The northeast-southwest orientation of the lakes has a great influence on the direction of caribou migrations through the region; (2) the region south of that outlined above has only scattered outcrops of bedrock (except along the south shore of Fond du Lac River where many high outcrops of Athabaska sandstone occur) and is mainly sandy and rolling. A prominent feature of the central part of the region is an extensive series of drumlins oriented north-south in the southern part of their range, changing to northeast-southwest and finally to east-west in the region just south of Stony Rapids. The region has several prominent eskers. A large part of the surface is covered by water in the form of marshes, rivers, and lakes in all stages of deposition, drainage, and maturity.

On the basis of vegetation two broad divisions also can be recognized. They agree quite well with the main topographic divisions and were identified by Halliday (1937) as the Northern Transition Section and the Northern Coniferous Section, respectively, of the Boreal Forest Region. The entire region, with the exception of the tundra stations to the northeast, is included in the Hudsonian Biotic Province of Dice (1943).

The use of the region by caribou varies widely and, until now, inexplicably. Generally, the caribou come into the region from the north and northeast in October and November and remain during the winter

until leaving for the north and northeast in April or May. During some years the caribou winter in a small number of fairly dense, but discrete, concentrations, whereas during other winters they are thinly scattered over large areas. In some years they range south to Cree Lake, even going as far as Turnor or Frobisher lakes; in others they remain close to Lake Athabaska and Fond du Lac River. They may remain in one and the same general region a whole season; in other winters they may shift their wintering grounds several times.

On the basis of the use of the region by man one salient observation stands out — the amazing completeness of the destruction by fire of mature, stable vegetation associations. From Lake Athabaska-Fond du Lac River-Black Lake south to Cree Lake and Methy Lake, and from Black Lake-Pasfield Lake-Cree Lake west to the Alberta boundary there is scarcely a square mile that has not been burned at least once and often many times. The only remnants of unburned vegetation exist on islands, attenuated peninsulas and possibly in some muskegs. Repeated burning in conjunction with the sandy soil has caused quite xeric conditions to develop, resulting in jack pine *(Pinus banksiana)* becoming the most common tree species. The herbaceous layer is poorly developed. The forest floor is usually bare, needle-covered, or has a thin growth of lichens. The influence of this burned, xeric condition of the winter range on the size and density of the caribou population cannot be over-emphasized, particularly in the light of the results of the snow studies given below.

Methods

Two basic techniques were used for this study. First, the distribution of caribou was determined by extensive air surveys. Numerous flights, totalling some 8,850 miles, were made in order to plot accurately the distribution of wintering caribou (Fig. 2). During the middle of the day in winter caribou generally rest in small bands on frozen lakes. Flights were usually made during the hours from 0900 to 1500 in order to take advantage of this behaviour and were flown at 800 to 1,000 feet above the ground. Tracks and numbers of individuals seen were noted along the flight lines, which had been plotted on topographic maps. This information was collated after each flight so that any shifts of the areas of caribou concentration could be detected.

Second, a series of snow observations were made at stations installed at frequent intervals from December 10, 1957 to April 11, 1958. Snow observations have been made at 114 formal and many informal stations (Fig. 3). The majority of stations was installed between February 16 and 28, 1958. The stations were generally arranged in pairs, one at the north or northwest edge of a lake or occasionally off the south or southeast shore of a peninsula or island, so as to sample snow that had not been violently disturbed by wind. The other member of the pair was a forest station situated on the north or northwest shore far enough from the lake shore so that drifted snow was avoided. Each set of snow observations took

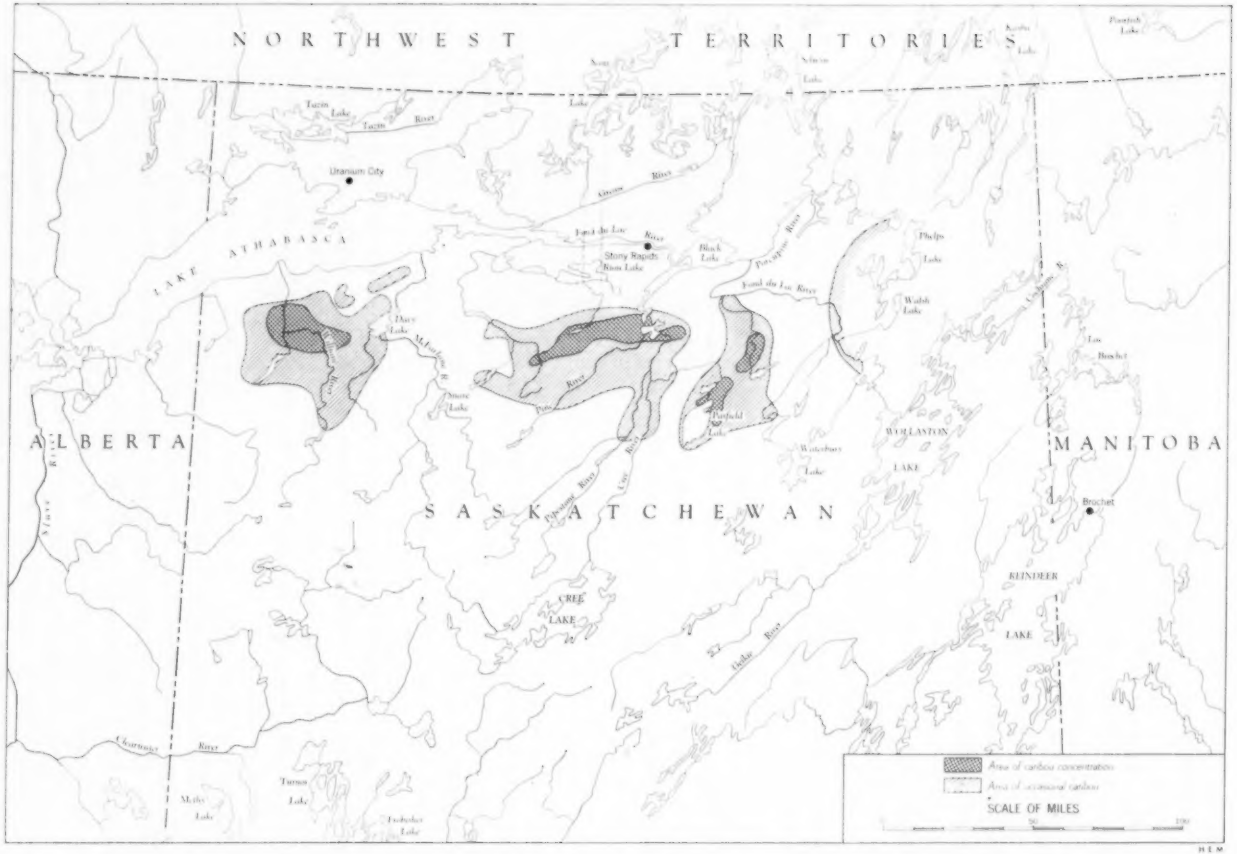

Fig. 2. Northern Saskatchewan and adjacent region, showing distribution of wintering caribou. Heavily shaded regions represent the areas of concentration and lightly shaded regions those of occasional caribou. The unshaded region represents the area of no caribou.

about 30 to 40 minutes to complete. Every effort was made to insure that forest stations were in situations that were similar as regards vegetation and topography and that lake stations were similar as regards exposure to wind.

The Committee on Snow and Soil Mechanics of the National Research Council of Canada kindly lent to the Canadian Wildlife Service a set of Standard Snow Instruments (Klein *et al.* 1950), which I used during this study. At each station the following data were taken: location of station, date, habitat, air temperature, pukak temperature (Pruitt 1959), vertical hardness of the snow surface, total depth, ground vegetation, and hardness of the snow to track depth. This last measurement was an improvisation that consisted of recording the resistance of the snow to pressure sufficient to make an artificial caribou track of a depth comparable to actual tracks that could be found in the vicinity. A vertical profile of the snow cover was exposed and the thickness, hardness, density, and grain size of each layer were measured and recorded. Since the Standard Snow Instruments were used, hardness was recorded as the pressure in gm. per sq. cm. necessary to collapse the structure of the snow of each layer, and density was calculated from the weight of a 500-cc. sample from each layer. In this system, therefore, hardness is a measure of the degree of cohesion between snow particles. It is an empirical expression of the condition dependent on crystal size, shape, contiguity, and strength of inter-crystal bonds. Calculations of density result in expressions of the ratio of the number of water (i.e. ice) molecules to air molecules in a given volume of snow. Grain size and type were recorded in reference to the classification put forward by the Committee. The number of layers in the profiles varied from one or two to as many as eight. A glossary of specialized snow terms is appended to this paper.

Results

A. Extensive survey

The survey flights revealed that the region could be divided into three categories on the basis of caribou distribution. First it must be understood that individual Barren Ground caribou may be found almost anywhere on the mainland of northern Canada at any season of the year. Some caribou winter far out on the tundra and others spend the summer well within the limit of trees. Therefore, even if a region is classified as having "no caribou", a very rare individual (the so-called "odd caribou" in Canadian parlance) may still be present. With this reservation in mind, most of the region studied was classified as having "no caribou." Next there was a series of caribou concentrations, or areas where every lake had caribou resting on it during the middle of the day, and where the snow cover was cut up by tracks and trails and pocked with feeding craters. Surrounding these areas of high concentration were fringe or marginal areas containing caribou in densities classified as "occasional." On survey flights over such

Fig. 2. Northern Saskatchewan and adjacent region, showing distribution of wintering caribou. Heavily shaded regions represent the areas of concentration and lightly shaded regions those of occasional caribou. The unshaded region represents the area of no caribou.

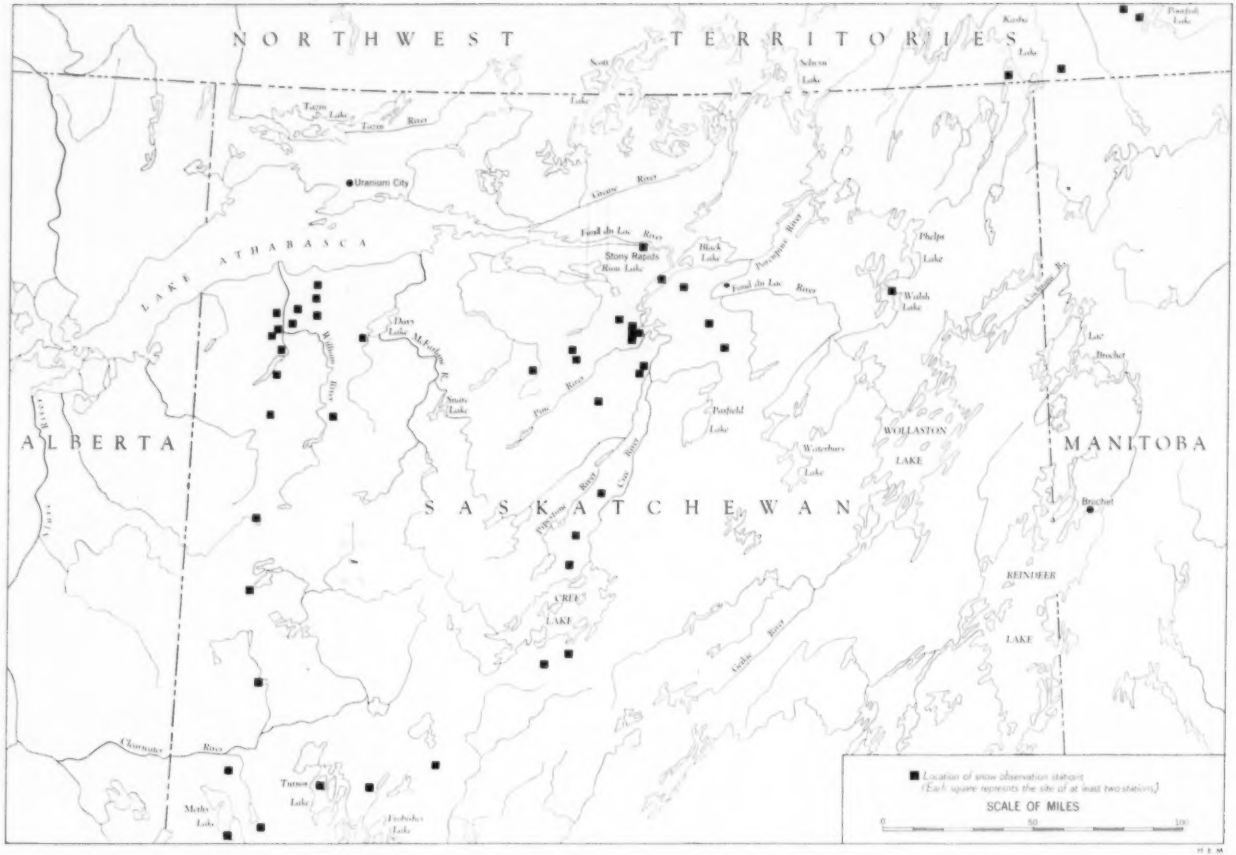

Fig. 3. Northern Saskatchewan and adjacent region, showing locations of snow observation stations. Each black square represents the site of at least two stations.

areas the observer sees only one or two tracks or trails every 2 or more miles. The boundary between the latter two divisions is usually quite sharp and is visible from the air as a marked difference in the appearance of the snow surface. These areas of concentration are outlined on Fig. 2 for February 1958. The heavily shaded regions represent the areas of concentration and lightly shaded regions those areas of occasional caribou.

Although an effort was made to establish snow stations in a systematic or grid pattern over the area, this scheme could not be adhered to. First there was the problem of poor maps, the Lake Athabaska sheet (National Topographic Series, Sheet 74 NW.) being particularly unreliable. Since the majority of proposed station sites could only be reached by light ski-equipped fixed-wing aircraft, there was a lower limit to the size of lakes on which it was possible to land and to take off. On account of the irregular outlines of the areas of varying caribou concentration many stations were shifted and established in, rather than outside of such areas. This applies particularly to those established by travelling on snowshoes or by dog team from the field camps, which were successively established in the areas of densest caribou concentration. Fig. 3 shows the positions of snow stations. Each square represents the site of at least two stations.

Fig. 3. Northern Saskatchewan and adjacent region, showing locations of snow observation stations. Each black square represents the site of at least two stations.

Forest or tree cover has a marked effect on reducing wind velocity (Geiger 1950). Wind is also one of the most effective factors in changing the characteristics of the snow cover. Therefore one would expect to find the snow cover on lakes consistently more modified than that in the adjacent forest. I found this to hold true. Therefore, data from lake, marsh, or non-forest stations have been kept separate from those from forest stations.

Table 1 gives mean values at the stations, segregated according to forest and lake and degree of caribou concentration for (a) the hardness of the hardest layers in the snow profiles, (b) the density of the densest layers, and (c) the thickness of the cover.

Inspection of the summary of a portion of the data in Table 1 reveals several important facts.

(1) The areas of heavy caribou concentrations were characterized by snow with the following features: (a) it was quite soft, the hardest layers ranged from 6.5 to 60 gm./sq. cm. for forest and from 50 to 700 gm./sq. cm. for lake stations; (b) it was light in weight, the densest layers ranged from 0.13 to 0.20 for forest and from 0.13 to 0.32 for lake stations; (c) it had a thickness below a critical 50 to 60 cm. at forest stations.

(2) The areas of occasional caribou were characterized by snow with these features: (a) it varied from soft to hard, the hardest layers ranged from 60 to 3,000 gm./sq. cm. for forest and from 50 to 6,000 gm./sq. cm. for lake stations; (b) it was denser than that under (1) and varied from 0.16 to 0.48 for forest and from 0.18 to 0.92 for lake stations; (c) thickness varied from 32 to 62 cm. for forest and from 20 to 38 cm. for lake stations.

(3) The area of nc caribou was characterized by snow with these features: (a) it varied from occasionally soft to frequently very hard, the hardest layers ranged from 35 to 7,000 gm./sq.cm. for forest and from

150 to 9,000 gm./sq.cm. for lake stations; (b) it had occasionally extremely dense layers, the densest layers ranged from 0.16 to 0.92 for forest and from 0.17 to 0.92 for lake stations (0.92 is the density of freshwater ice); (c) thickness of the cover at forest stations was well above the critical value.

B. Intensive Observations

All snow covers undergo a process of maturation during which their morphology (thickness, hardness, density, grain size and structure) undergoes a series of well-known and fairly well-understood changes (Bader *et al.* 1954; Klein *et al.* 1950). These changes are believed to be the result of temperature and moisture gradients extending from the substrate, whether earth, rock, freshwater ice, or sea ice, through the snow cover to the air above. Striking as these changes are, their sequence can be completely upset and changed by wind strong enough to move the particles of the snow cover. Whenever wind is combined with high temperatures, or when liquid precipitation with its great supply of heat occurs, the changes produced in the snow cover are very conspicuous.

Such changes occurred in northern Saskatchewan during the winter of this study. From January 4 to 8, 1958 a sequence of weather disturbances passed over the region. In the neighborhood of Cree Lake rain fell for 5 hours at one time during this period, probably on January 4, according to Mr. Martin Engemann, resident of the region. This was followed by a cold snap, which caused an ice layer to form on the snow cover. The ice layer was found at the stations to the southwest, west and northwest of Cree Lake. On a flight on January 4, from Stony Rapids to the camp at 58°37′N., 105°50′W., the aircraft encountered rain at approximately 800 feet above the ground. This period of precipitation was followed by high winds (recorded as fresh to strong) and temperatures as high as +2°C., and later by the normal of −18°C. and lower. Before the storm the snow cover in the vicinity of the camp (in an area of heavy caribou concentration) had a hardness of the order of 6 to 15 gm./sq.cm. and a density of 0.05 to 0.15. After the storm the hardness at adjacent or comparable stations was of the order of 20 to 25 gm./sq.cm. and the density 0.12 to 0.18. The time of the storm and the period immediately following it were marked by a definite movement of caribou out of the area, probably northward. Counts of caribou on the lake where the camp was situated dropped from as many as several hundred individuals per day to five or ten per day. Survey flights on January 12 and 13 revealed that the southern boundary of the area of heavy concentration was some 15 to 20 miles north of the camp, whereas before the storm it had been an approximately equal distance south of the camp.

A similar sequence of events occurred on February 6 to 8, 1958 in the vicinity of the camp at 58°49′N., 105°52′W. Before the storm the hardness of the hardest layer of forest snow was of the order of 6 to 20 gm./sq.cm. and the density of the densest layer 0.03 to 0.17. After the storm the

Table 1. Hardness of hardest snow layers (gm./sq.cm.); specific density of densest snow layers; depth of snow (cm.).

Density of caribou	Concentration	Occasional	No
		Forest	
Snow hardness			
Mean	34	469	993
Range	6.5 — 60	60 — 3,000	35 — 7,000
Number of stations	19	12	23
Snow density			
Mean	0.17	0.25	0.31
Range	0.13 — 0.20	0.16 — 0.48	0.16 — 0.92
Number of stations	19	12	23
Snow depth			
Mean	45	45	56
Range	19 — 59	32 — 62	31 — 82
Number of stations	20	11	23
		Lake	
Snow hardness			
Mean	291	1,954	3,016
Range	50 — 700	50 — 6,000	150 — 9,000
Number of stations	16	12	25
Snow density			
Mean	0.19	0.35	0.49
Range	0.13 — 0.32	0.18 — 0.92	0.17 — 0.92
Number of stations	18	10	25
Snow depth			
Mean	33	30	41
Range	21 — 43	20 — 38	19 — 46
Number of stations	16	12	25

hardness ranged from 5 to 40 gm./sq.cm. and the density from 0.12 to 0.20. This particular storm is of interest since it developed barchans on the camp lake. Again, the caribou concentration decreased markedly.

Individual bands of caribou move from areas of greater hardness to areas of smaller hardness, and from areas of higher density to areas of lower density, but it might be well to point out here that the hindrance effect of snow appears to be relative. Whereas there appears to be a critical upper limit for each of these characteristics, the hardness range that causes one band of caribou or the caribou in one area to move away, may, in other distant areas, be the hardness range into which a band will move from an area with a still greater hardness. This relationship applies also to density. The caribou's threshold of sensitivity to the hindrance effect appears to rise as the winter progresses and the snow undergoes its maturation process, resulting in a progressive increase in hardness and

density. That is, a hardness that in early winter would cause an exodus of caribou from a region appears to be tolerated by them in late winter as long as the critical limit is not exceeded. Thus sequential snow-caribou correlations are necessary; isolated observations are probably of little value and indeed may be misleading.

It might also be well to point out that hard or dense layers in the snow cover appear to have different hindrance effects depending on whether the layer in question occurs near the centre or top of the snow cover or at the base. A very thin but hard layer on the surface of the snow cover has a far larger hindrance effect than the same layer at the base. Both adults and fawns were observed to sink 10 to 12 cm. in snow having a hardness of 400 gm./sq.cm. (58°49′N., 105°52′W., February 8, 1958), they broke through a layer with a hardness of 600 gm./sq.cm. and walked on the surface of a layer with a hardness of 1500 gm./sq.cm. The tracks of the adults measured 105 x 85 mm., without dew claws. (58°47′N., 105°56′W., February 10, 1958). The dew claws of caribou are not effective in providing flotation until the snow cover reaches a thickness of 3.5 to 4 cm. A snow observation station was established at a spot where caribou were observed to have difficulty in walking. The snow at this spot was 33 cm. deep and showed a critical layer 2 cm. thick extending from 17 to 19 cm. above the substrate. This layer had a hardness of 900 gm./sq.cm. and a density of 0.31. The hardness above the critical layer ranged from 1 gm./sq.cm. to 80 gm./sq.cm., and the hardness below the layer was 200 gm./sq.cm. Density above the critical layer ranged from 0.02 to 0.21 and below it was 0.14. (58°49′N., 105°52′W., January 28, 1958).

One must not assume that snow acts solely as a hindrance to caribou progression. Since the caribou is primarily a grazer, not a browser, its food supply must be excavated from beneath the snow cover. The act of pawing through the snow cover (digging a "feeding crater") is an integral part of the complex of behavioural patterns that govern the caribou. It gives every indication of being a "consummatory act" (Tinbergen 1951). Consummatory acts are repetitive, stereotyped actions that deviate little, if at all, from a set pattern. They occur after, and as a culmination of, longer periods of less circumscribed "appetitive behaviour", which is strongly influenced by environmental stimuli. This shows what a vital role such adaptations to snow must have played in the evolution of caribou, since consummatory acts are such primary ones as actual eating, nest construction, copulation, etc.

The usual feeding crater observed during the winter 1957-8 exposed an area of substrate approximately 15 by 35 cm. While pawing through the snow the caribou trampled, dug out or otherwise disturbed the snow in a patch approximately 1 by 2 metres. Regardless of the condition of the snow before being disturbed, after cratering its hardness and density increased markedly. A period of approximately 4 hours at very low temperatures is sufficient to "set" disturbed taiga snow to a hardness that will support the weight of a man (approximately 2,000 to 3,000 gm./sq.cm.

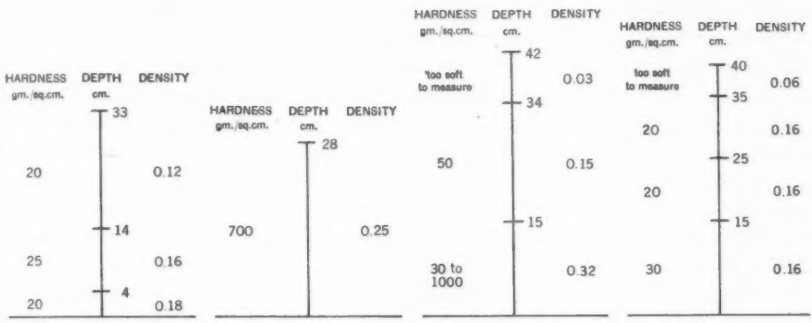

Fig. 4. **Fig. 5.** **Fig. 6.** **Fig. 7.**

Fig. 4. Undisturbed snow, Jan. 5, 1858, at 58°37′N., 105°50′W.

Fig. 5. Snow excavated from a feeding crater, Jan. 6, 1958, approximately 300 yards from station of Fig. 4.

Fig. 6. Snow disturbed by crater excavation but not trampled, Jan. 28, 1958, on a heavily cratered and trampled jackpine slope at 58°49′N., 105°52′W.

Fig. 7. Undisturbed snow, Jan. 29, 1958, approximately 500 yards from station of Fig. 6.

hardness, Elsner and Pruitt 1959). In January 1958 I measured the snow at four stations with the results shown in Figs. 4 to 7.

I have observed that caribou will feed in a previously cratered area only once more, after which the snow becomes so hard that they move on to softer snow. I have observed and calculated that mature, open jack pine forest will show 366 craters per acre (904 craters per hectare), which means that a total of 732 craters can be dug per acre before the snow becomes too hard. Apparently on account of social interactions one acre rarely shows more than about 366 feeding craters at any one time. This number of excavations rather effectively covers the whole surface with disturbed snow. Another factor, that of variable temperature, enters the picture here, since at lower temperatures disturbed snow will set quicker and harder than at higher temperatures.

Since caribou use a given spot for feeding only twice, it is evident that this behaviour alone is sufficient to account for a large share of their daily movements in winter. Because on lakes the snow usually is not as deep as in the forest and especially since it is usually harder (its surface is frequently supporting caribou), wintering bands use snow-covered lakes as "escape cover" or "loafing cover." Undoubtedly, ideal conditions for escape or loafing cover would be provided by very hard lake snow. In order that such snow conditions develop the winds would have to be so strong that they would reach the feeding grounds through the trees and modify the snow there beyond the critical thresholds. The bands usually bed down more than 75 to 100 yards from shore. It is noteworthy that this is the distance to which the wind-shadow effect of mature spruce forest extends on a lake. Forestward within this shadow the snow becomes progressively

more like forest snow; lakeward beyond the shadow it is harder and denser. The bands stay on the lakes during the middle of the day, usually from about 0900 until 1500 hours. During the bedding period caribou move around several times, each animal making a series of smooth semi-circular beds in the snow. When they move to feed they go to the nearest shore, and then return to their bedding ground or loafing cover. For the next feeding period they go to the same feeding area, or if the snow there is too hard they move beyond it until they encounter soft snow. In this fashion the bands feed at progressively greater distances from their loafing cover. Finally they pass the ridge and are in sight of the next lake and it is then used as escape or loafing cover. In this manner the bands of caribou move back and forth through the snow on their winter range.

C. Spring Movements

Since caribou appear to be responsive to variations in the hardness and density of the snow through which they wade during about two-thirds of their annual cycle, it logically follows that at least some aspects of their spectacular annual migrations are correlated with nival factors. This appears to be true.

The threshold of sensitivity appears to be reached by snow with a hardness of about 50 gm./sq.cm. for forest snow and 500 gm./sq.cm. for lake snow. The density threshold appears to be about 0.19 or 0.20 for forest snow and about 0.25 or 0.30 for lake snow. The depth threshold appears to be about 60 cm.

As the insolation increases in the spring the snow develops a sun crust ("na-hó-t(ch)ran" in the local Chipewyan dialect) and starts to settle. This settling is only the visible manifestation of morphological changes occurring in the snow cover. These changes are measured by the snow instruments as increases in hardness and density, although they are actually caused by growth of the snow particles with an accompanying decrease in particle number. At the time when these changes take place there also occurs a change in the behavioural pattern of the caribou. Individuals or small groups now frequently break away from a larger band and run or bound in a large circle. This behaviour is quite noticeable during air observation of tracks. It is noteworthy that bounding is characteristic of ungulates when they find themselves in snow above their critical depth. There may be a resemblance between this behaviour and the increased sensitivity to external stimuli during periods of thaw noted by Darling (1937) in red deer *(Cervus elaphus)*.

In the spring when the forest snow attains a surface hardness of from 300 to 500 gm./sq.cm. and a density of the order of 0.30, the caribou react in the same way as that following a similar change produced by a winter storm: they move toward softer and lighter snow. Settling, crusting, and melting advance gradually through the taiga toward the limit of trees, herding the caribou along. Sometimes the progress of thaw is interrupted

by meteorological events that cause intense freezing of the melting snow cover. At such times the snow becomes extremely hard. Surface hardness may rise to 3,000 gm./sq.cm. or more in a few hours. Density does not change much, since it is governed by the water content of the individual layer whether frozen or not. At the time of a spring cold snap the caribou cease their movement along the hardness gradient, simply because the gradient no longer exists. The migration stops. The brittle crusts common at this time of the year under such conditions may be a factor deterring movement because of sheer discomfort or pain accompanying constant breaking through the crust. After the cold snap is over or after the cold night has passed and the sun again acts on the snow cover, the migration is resumed along the hardness gradient.

On April 24, 1958, after the caribou migration had already passed through the Stony Rapids region, I flew a survey in northern Saskatchewan and southern District of Mackenzie (National Topographic Series, Sheet 74 NE., Black Lake and Sheet 75 SE., Wholdaia Lake). The ground in the vicinity of Stony Rapids was 90 per cent bare of snow, but approximately 30 to 35 miles to the northwest only the south slopes were bare. In the vicinity of Dunvegan Lake only qamaniq (Pruitt 1957, 1959) and steep south slopes were bare, lake surfaces were still white, and showed no signs of slush. This state of thaw occurred along a line running from approximately 60°N., 107°W. through the northern part of Wignes Lake and thence north of Ingalls Lake. In the region near Jardine, Rutledge, Brûlé, Atkinson, and Mountain lakes there was even 0.1 or 0.2 qali (Pruitt, 1958) remaining. From Hostile Lake on northward the snow cover was complete, even the south-facing slopes of eskers were covered and snow cornices were intact. From the vicinity of Gozdz Lake northward the snow surface was crystalline and showed light and dark wind streaks. These wind streaks are caused by parallel alignment of the frost crystals on the snow surface. The migrating caribou were north of the region where the lakes were dark with slush and south of the region where the snow cover was complete (including 0.1 qali). This region was characterized by having only qamaniq and the steep south slopes of eskers bare of snow.

Possibly the presence of 0.1 or 0.2 qali or the presence of bare qamaniq, both identifiable from the air, may be used as indicators of the progression toward the tundra of the spring thaw and of the critical limits of the nival factors that govern the spring migration of the caribou from taiga to tundra.

Undoubtedly, similar correlations between snow conditions and caribou movement could be obtained during the fall migration from the tundra to the taiga.

Discussion

From the foregoing exposition it is evident that the snow cover through which the caribou wade and from beneath which they gather most of their

food exerts a profound influence on their behaviour, migration and species survival. Formozov (1946), in his classic work on the biological effects of snow, classified mammals as chionophobes (avoiding snow), chioneuphores (adapted to snow) and chionophiles (highly adapted to snow or even restricted to snow). Examples of chionophobes, according to Formozov, are the smaller cats and the steppe antelopes. Examples of chioneuphores are mice, wolverine, fox, voles, etc., whereas the varying or "hoofed" lemming and the snowshoe hare are examples of chionophiles. Formozov classified the Old World reindeer as a chioneuphore. Since the New World caribou, because of its migrations, is subjected to snow factors for two-thirds of its annual cycle and because it exhibits behavioural and morphological adaptations to snow we are justified in classifying the Barren Ground caribou as a chionophile or an animal that is highly adapted to life on snow. Indeed, the name "snow caribou" would be more suitable for this species than is the term "Barren Ground caribou."

As my snow studies progressed it became evident that the wintering caribou in northern Saskatchewan were surrounded by a fence of snow having different characteristics from that in which they aggregated and that they were herded about over the countryside by this fence. To both the north and the south there was snow of greater depth than in the areas of concentration. To the south and southwest there was a sharp nival ecotone between soft, light taiga snow and hard, dense or iced snow almost temperate in its characteristics. The areas of caribou concentration had a snow cover that was softer, lighter, and thinner than that in the surrounding areas. Whereas the snow in the areas of occasional caribou was at times as soft and as light as that in the concentration areas it was at other times much harder and denser. The areas of no caribou had snow that consistently exhibited greater hardness, density or depth (occasionally all three qualities) than that of the areas of concentration. Variations in hardness appeared to influence caribou distribution more than variations in density. Obviously the presence of suitable food under the snow cover is also a factor of major importance as far as wintering localities are concerned. Under conditions of little modification of the winter range by man, probably the effect of nival factors was more prominent. Under such primeval conditions, before the extensive destruction of the winter range took place, nival factors probably were responsible for the location and density of wintering bands. Under present conditions the lack of food over extensive areas must be reckoned with.

Since snow conditions may prevent the wintering caribou from using extensive regions that are potential wintering grounds as far as food supply is concerned, it is obvious that winter range for any given number of animals must be substantially larger than the amount calculated from food intake per caribou per day and range recovery. In other words, a given amount of winter range can only support safely a much smaller number of caribou than that calculated on the basis of food intake and range recovery, because snow conditions in different years may herd the caribou about so

that they cannot use all the range that is vegetationally suitable. Calculations of the carrying capacity of caribou winter range must be related to the caribou's ability to dig feeding craters, the number of craters that can be dug per unit area in a given habitat type and the amount of food secured per crater.

Ideal snow conditions for caribou winter range appear to be (1) hardness not over 60 gm./sq.cm. for forest snow and not over 700 gm./sq.cm. for lake snow; (2) density not over 0.20 for forest snow and not over 0.32 for lake snow; (3) depth not over 50 or 60 cm.; (4) continuous low temperatures during the snow season (no invasions of moist tropical air masses) and low wind speeds during this period. Undoubtedly, if sufficient meteorological and climatological data were available, areas where such conditions are the rule could be mapped out. Of all the vegetationally suitable winter range those parts that are nivally suitable are the most valuable as far as species survival is concerned and should receive the maximum possible protection from artificial modification.

Nasimovich (1955) described similar reactions of Eurasian wild reindeer to nival conditions. The thresholds of sensitivity he recorded were in some instances significantly higher than those reported here. Thus it would appear that the behavioural responses of New World caribou to nival conditions are sufficiently different from those of Old World reindeer so that direct comparisons are not valid.

It is not by accident that all references to caribou in this paper are in terms of individuals or bands. Since the areas of wintering concentrations and the timing, direction and speed of migration are intimately related to the characteristics of the snow cover, I suspect that the actual geographic location of the migration routes themselves are governed by snow (and topography). Thus the "herds" of caribou (Banfield 1954) are actually the summation of individuals and bands aggregated because of the fencing or restricting action of snow. The discreteness of the several "herds" is but a biological reaction to areas or channels of softer, lighter, and thinner snow cover between and among areas of harder, denser, and thicker snow cover. If sufficient meteorological and climatological data were available this hypothesis undoubtedly could be tested.

Thus it appears that a profitable approach to the problem of caribou migration would be to develop further the idea of nivally suitable pathways and wintering areas or "deer passes." This approach has been singularly successful in dealing with the problems of migratory birds, resulting in the "flyway" concept.

On many survey flights during early winter and midwinter I observed that the presence of barchans on lakes was a quite reliable indicator of the lack of caribou in the surrounding area. Obviously barchans themselves had little to do with the caribou, but as indicators of nival environment they seem to be of value. As the winter progressed and as the several storms mentioned above passed over the region barchans began to appear

on lakes in the areas of occasional caribou and rarely in areas of concentration. When barchans appear on fall or early winter snow it means that the entire snow cover down to the substrate has been moved by the wind and is therefore hard. Barchans in late winter may be formed on top of the snow cover, particularly if there is a harder layer midway through the cover. I observed this condition on February 8, 1958 on a lake where the camp at 58°49′N., 105°52′W. was situated. The snow cover was 21 cm. thick and had a hardness ranging from 15 gm./sq.cm. to 50 gm./sq.cm. and densities ranging from 0.14 to 0.20. On top of this cover were barchans made by the storm of February 6 to 7, 1958. The barchans had a hardness of 400 gm./sq.cm. and a density of 0.29.

Conversely, the presence of qali (Pruitt 1958) indicates a lack of wind and usually soft and light snow. Since this phenomenon, as well as barchans, can be readily seen from the air, these two snow formations give promise of being valuable indicators of the nival environment. Further observations of barchans and qali in relation to caribou distribution might disclose principles which could be of value in plotting wintering grounds and fall migration routes.

Suggestions for future work

The National Research Council Standard Snow Instruments should be used, if for no other reason than standardization of data. Certainly some modifications could be made in the instruments themselves and in their packaging. The hardness gauge is sometimes difficult to use because of the large size of the pressure disc necessary for measuring thin layers of very soft snow (1 to 10 gm./sq.cm.). Possibly an additional gauge with a weaker spring could be devised, thus permitting a smaller pressure disc to be used.

I would suggest that for biological purposes instead of the present technique of cutting two or four 250-cc. samples of snow for density measurement that a more suitable cutter be devised. This cutter could contain 500-cc. and be so shaped that it could be used to weigh the snow directly. It would be a simple matter to adjust the scales to the tare of the cutter. This procedure would eliminate the need for the present pan and hanging chains.

I would also suggest that some sort of wind shield be devised for the snowkit when the scale is assembled, possibly along the pattern of the wind shield on a Coleman stove. It is virtually impossible to obtain an accurate weight whenever there is a wind blowing. This is not too important when working in the forest, but on lakes and on the tundra it is a constant worry.

I found that because mittens or even gloves were too clumsy to wear when taking snow measurements, that tape or heavy cotton twine wound around the hardness gauges made these chunks of brass more comfortable to handle at extreme low temperatures.

Although the Cessna 180 aircraft on skis served us well, a more rugged type of aircraft would be better. If any sort of systematic grid series of stations is contemplated then I urge that a rotor-winged aircraft be used for those stations which cannot be reached by conventional fixed-wing aircraft. The present study suffered from my inability to reach stations which fell on or near lakes too small for the Cessna 180 and from my inability to sample sufficiently the uplands, and the interiors of extensive burns.

I believe that the "track depth" measurement is promising and should be perfected. One of the first questions to be answered is: what are the foot loadings for caribou of various ages and weights *in the winter?* This qualification is important since caribou hoofs differ markedly in size from summer to winter. The Chipewyans have different names for short summer hoofs (eh-keh-gúna-ne-dúa), for long winter hoofs (eh-keh-gúna-ne-néth), and for winter hoofs when they become abraded and broken at the tips in spring (eh-keh-gúna-nah-tRé). Seton (1909) stated that reindeer feet are loaded at 2 pounds per square inch (357.2 gm./sq.cm.), contrasted with moose *(Alces americana)* which are loaded at 8 pounds per square inch. Nasimovich, however, (1955) listed wild Altai reindeer as having foot loadings of only 140-180 gm./sq.cm. Once a satisfactory artificial hoof is devised the procedure should be to measure the depth it penetrates at loadings approximating those of caribou of various ages and weights. A wealth of information could be gained from isolated tracks by an observer familiar with this measurement and its use.

It is evident from the data presented in this paper that the snow cover on the caribou winter range may vary greatly in its characteristics over a comparatively short distance and time. Therefore it is clear that conventional snow data as reported by the existing net of meteorological observatories are not only insufficient but may actually be misleading. The data for biological purposes apparently will have to be collected by the biologists themselves, at least until many more meteorological observatories have been established in far greater concentration than that existing at present and until the observers have been trained in an ecological approach which is, to temperate-zone people, somewhat esoteric. Because of the variability of the snow cover over short distances a large number of snow stations are necessary in order to gather data that are reliable. I consider my 114 stations as the absolute minimum number.

Since snow cover varies from winter to winter as well as from place to place, it would be well to sample it in years of little snow as well as in years of much snow. Various parts of the winter range should be sampled. There should be a comparison between snow and its relation to caribou on unburned and on burned winter range. It would be extremely interesting to investigate the nival environment of those bands of caribou that spend the winter on the tundra. Such an investigation might well reveal facets of caribou-snow relationships that would go far toward formulating general principles. Are these caribou in pockets of suitable snow? Are they

channelled into cul-de-sacs of suitable snow in the fall and then have their routes of egress cut off by unsuitable snow conditions? What sort of physical condition do these caribou show in relation to those that winter in the taiga? This sort of information probably would be of great value in interpreting Pleistocene climates and the present composition and distribution of the mammalian fauna.

Undoubtedly there is a relationship between the areas where caribou habitually winter, their migration routes (and possibly the "pockets" of caribou that winter on the tundra) and the routes usually taken by cyclonic disturbances as they move across the continent. The tracks and the frequency of these storms are fairly well known. Do these air masses regularly deposit their load of snow along certain lines? Are there certain regions where polar air is more liable to encounter moist tropical air masses and how are these regions situated in relation to the known usual or specific wintering grounds? Finally, has the recent warming trend in the climate produced any northward shift of the zone in which winter thaw or rain may occur? This may be of extreme importance for the overall picture of caribou populations and movements. These questions could be answered, I believe, by a trained climatologist who is familiar with the ecological aspects of the problem. If these questions were answered and the various phenomena plotted on maps I suspect that many of our questions regarding caribou distribution and movements could be at least partially answered.

I believe that investigation of the behavioural aspects of the caribou-snow relationship would be a fruitful line of endeavour. When the varying "hindrance factors" of the snow cover reach critical thresholds they appear to act as releasers of migratory behaviour. The peculiar bounding circles that caribou describe when the spring snow conditions approach their limits of hardness and density tolerance should be investigated further. Is this behavior initiated on the edges of the region that is nivally suitable? Darling (1937) attributed the increased irritability in red deer to changes in atmospheric moisture. Further work should be done also on investigating the level of integration of such acts as pawing a feeding crater. The behaviour exhibited by a caribou in preparing to lie down on a snow-covered lake is interesting and deserves interpretation. A great deal of behavioural work can be done from movie films, especially if they are taken by an observer who is also familiar with the characteristics of the particular type of snow cover concerned.

Summary

1. During the winter 1957-1958 114 snow observation stations were established in parts of northern Saskatchewan and the southern Northwest Territories. Approximately 8,850 miles were flown at low altitudes over the region. During these flights the positions of bands and wintering individuals of Barren Ground caribou *(Rangifer arcticus)* were plotted on topographic maps.

2. Numerous ground observations were made of caribou behaviour in relation to snow conditions.

3. The areas of heavy caribou concentration were characterized by snow cover that was quite soft, light, and thin (hardness range of 6.5 to 60 gm./sq.cm. for forest stations and 50 to 700 gm./sq.cm. for lake stations; density range of 0.13 to 0.20 for forest stations and 0.13 to 0.32 for lake stations; thickness range of 19 to 59 cm.).

4. The areas of no caribou were characterized by snow cover that was sometimes soft but also could be very hard, dense, and thick (hardness range of 35 to 7,000 gm./sq.cm. for forest stations and 150 to 9,000 gm./sq.cm. for lake stations; density range of 0.16 to 0.92 for forest stations and 0.17 to 0.92 for lake stations; thickness range of 19 to 82 cm.).

5. Caribou appear to have a threshold of sensitivity to the hardness, density and thickness of the snow cover. The threshold of hardness sensitivity appears to be approximately 50 gm./sq.cm. for forest snow and 500 gm./sq.cm. for lake snow. The density threshold appears to be approximately 0.19 or 0.20 for forest snow and 0.25 or 0.30 for lake snow. The thickness threshold appears to be approximately 60 cm. When these thresholds are exceeded caribou react by moving until they encounter snow of smaller hardness, density or thickness.

6. Caribou will dig feeding craters only twice in a given unit of snow after which it becomes so hard that they seek undisturbed snow for feeding.

7. Some of the relationships of snow to the evolution, behaviour, species survival and management of caribou are discussed.

8. Various aspects of necessary future research and improvements in techniques are enumerated and discussed.

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snow survey. I am indebted to Dr. Frederick C. Dean of the University of Alaska for critically reading the manuscript.

Glossary of specialized snow terms

Barchan — crescent-shaped drift of snow (or sand), convex upwind, with gentle windward and steep leeward slopes.

Chionophobe — an animal that on account of morphological or behavioural specializations is unable to adapt itself to snowy conditions.

Chioneuphore — an animal that is able to exist in snowy regions, but does not have special morphological or behavioural adaptations to snow.

Chionophile — an animal that possesses definite morphological or behavioural adaptations enabling it to live in snowy regions, and that is limited in its distribution to snowy regions.

Nival — adjective referring to snow.

Pukak — Kobuk Valley (Alaska) Eskimo term for the fragile lattice-like structure of snow grains formed at the base of a snow cover by redistribution of water molecules by sublimation. Also called "depth hoar".

Qali — Kobuk Valley Eskimo term for the snow that collects on trees, as distinguished from api, the snow that collects on the ground.

Qamaniq — Kobuk Valley Eskimo term for the bowl-shaped depression in the snow cover under coniferous trees.

Sun crust — the crust that forms on the surface of a snow cover in the spring when the sun is high enough to cause slight melting of the topmost layer during the day, which refreezes at night.

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REVIEW

MOONLIGHT AT MIDDAY

By SALLY CARRIGHAR. *New York: Alfred A. Knopf, 1958. 8½ x 5¾ inches; xx + 392 + viii pages, sketch map, numerous illustrations. $7.25 (in Canada).*

The reader should not be put off by the words on the dust-jacket, or "The Forty-Ninth Star" preface which is obviously a topical afterthought added during final editing or publication. This is not just another book pretending to tell all about Alaska while really aiming to cash in on recent interest and the excitement of Alaska's giant step from territorial status to full statehood. It is much better than that because it is about a part of the "Great Land" that Miss Carrighar called home for almost 10 years, and consequently it is written not only with authority but with insight and sensitivity. Every Alaskan has his or her own special "Alaska" and Sally Carrighar's can be roughly identified on a map by two lines diverging westward from Fairbanks toward the International Dateline, one passing a little north of Kotzebue, the other a little south of Unalakleet. Her previous books were about the flora and fauna of places she had known: the Sierras of California, Jackson Hole in Wyoming, and the Bering Sea and Arctic coasts of Alaska. In this book the focus shifts to the people who inhabit a region and their ways of life. It also turns inward to the mind of the author, for in many ways this is a personal journal.

The contents appear in three parts. The first part comprises about two-thirds of the book, which is fortunate because it is by far the best. From its title "A Fine, Complete People", this can be described as a fine complete piece of writing, beautifully blending three intensely interesting and provocative themes into one harmonious whole. The prime subject, the Eskimo caught between two cultures, is a familiar topic, which nevertheless still calls urgently for the sort of restatement given here. Miss Carrighar takes up key aspects of the Eskimo's present way of life as she found it at Unalakleet, an Eskimo village where the old ways are still strongly held although they are being modified by contacts with the white man's ways, represented by the Bureau of Indian Affairs, the missionary, and the trader; at Nome, a white man's town in which the Eskimo account for about half of the population but is culturally adrift; and at big towns like Fairbanks, or in the vicinities of military installations, where the Eskimo is overwhelmed by the worst and most destructive elements of the new culture. All through this discussion there runs the theme suggested by the title of the first chapter, "Stormy Route to a Quiet Mind", in which the author expresses her deep personal indebtedness to the Eskimo without becoming maudlin. From time to time the Eskimo's old way of life is held as a mirror to our own culture and as a comment upon those trends within it that threaten to destroy us spiritually if not physically.

The narrative of the other two short parts reads unevenly and they are disappointing after the excellent opening. The author has not only tried to compress several incompatible elements into too small a space, she has also adopted several styles unnatural to her special talents, which may have been intended to fit the subject matter, but which appear to me as inept imitations of several stock styles. Best is the "Egg and I" style used in recounting her struggles to "outwit the Arctic" and describing the tangled "supply lines" in the part entitled "Modern Pioneering", but this part is padded with three chapters sounding like a government leaflet for

prospective settlers, which might have been presented as an appendix, or even by referring the reader to the readily available sources upon which they drew. The final part "Alaska Summons its Own" attempts to present the essential Alaska in three rather heavily symbolic chapters. The first, dealing with an old gold prospector, reads like a "My Most Unforgettable Character" from *The Reader's Digest*. The second, about a sanity hearing and its aftermath under Alaska's commitment procedure now mercifully abolished, might be the reporting of a backwoods Rebecca West. The last chapter is a contrived scene in which the reader is introduced to Fairbanks' leading citizens in the lobby of the Nordale Hotel on the last night of Alaska's biggest guessing game, the Nenana Ice Pool. Although this last chapter reads like something Edna Ferber decided not to include in her Alaskan novel *Ice Palace* the book as a whole can be well recommended.

GEORGE W. ROGERS

INSTITUTE NEWS

Gifts to the library

The Institute library acknowledges with thanks gifts of books and reprints from the following persons and organizations:

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Consolidation of the offices in the United States

In August of this year all the administrative functions of the U.S. offices were consolidated in Washington where an enlarged staff will handle the centralized records and procedure. The office has been remodelled and newly decorated, and facilities and equipment have been modified or expanded to handle the increased volume of work.

Dr. Walter A. Wood

Dr. Walter Wood, Director of the New York office since 1945, retired from the position in June this year and was elected to the Board of Governors filling the vacancy left when Dr. M. Westergaard resigned from the Board last year.

Library search and information service

The Institute Library in Montreal now offers a library search and information

service. Experience had shown an area in which the information services previously offered were ineffective. The Arctic Institute of North America has been carrying out large research projects under contract and has also filled many requests for information that required a few hours search, but compilations involving a few days or weeks of work could not be made effectively by the available staff. The library is now supported by a consultant service covering all subjects at the highest level, so that authoritative summaries are available in a very short time. The Arctic Institute of North America is unique in its ability to provide this service for the arctic areas. The program is offered as a service to the community as it is only charged on a cost and overhead basis, and it has already been used by several companies.

NORTHERN NEWS

Ptarmigan studies, 1958

The summer of 1958 was the third and final season of a project begun in 1956 on the ecology and distribution of ptarmigan (avian genus *Lagopus*) in western North America. In 1956 *L. mutus* and *L. lagopus* were investigated in one area in central Alaska; in 1957 the same two species and *leucurus* were studied intensively in Chilkat Pass, northwestern British Columbia. To test more extensively certain hypotheses regarding the distribution of ptarmigan, the writer visited widely separated alpine arctic areas in 1958 from Mount Rainier, Washington, to Eagle Creek, central Alaska. The data have been presented and discussed at length in a report submitted to the Arctic Institute; only a brief summary of work in 1958 and the general results of the entire study are given here.

Work in 1958

Breeding schedule of ptarmigan: Although the data are inadequate for conclusive statements, it appears that there is very little difference among the nesting times of the three species where they occupy the same general areas. Furthermore, the data show almost no delay in nesting when latitudinally separated populations of one species are compared in a given year. The calendar dates of breeding events at Chilkat Pass differed in 1957 and 1958, with 1958 being from 1 to 2 weeks ahead of the previous year. However, all three ptarmigan seemed to be affected equally.

Banding and populations: Populations of *L. lagopus* remained stable on the one-square-mile Chilkat Pass study area in 1957 and 1958; 39 pairs were seen both years. Of 56 *lagopus* (38 adults) banded on the study area in 1957, eight were found there in 1958. All except one had been banded as adults. A marked degree of philopatry was shown by the recaptured birds as all were within 300 yards of their banding place. One adult male mated with a different hen in 1958, but occupied the same territory as in 1957. Another pair remained mated for two years and held the same territory each year. At Eagle Creek, Alaska, populations of *mutus* (the more common species of *Lagopus* in the area) were low in 1956 (30 pairs in 25 square miles) and remained at about the same level, or perhaps slightly lower, in 1957 and 1958.

Vegetation studies: Details of vegetation form in territories, nest sites and brood covers were recorded in 1958 by means of a modification of Dansereau's

pictorial method (Dansereau, P. 1957. Biogeography . . . an ecological perspective. pp. 147-52). The results of the vegetation surveys, correlated with data obtained previously, are included in the project summary.

Project summary

Of special interest with regard to new life history information obtained in this research are (1) indications of the strength of male-female bonds in the species *lagopus*, (2) an apparent synchronism of nesting as discussed above, (3) low mortality of chicks during the summer, (4) rapid development of the young, (5) brood movements in July and August and (6) food habits (resulting from the analysis of approximately 170 crops).

L. mutus was found to breed in a zone characterized by shrubs less than 3 feet tall as opposed to the taller shrubs found in areas selected by *lagopus*. However, the important feature in habitat selection appeared to be the virtual absence of overhead vegetation in places used by male *mutus* as centers of activity within the territory, and the consistent presence of overhead concealment in places used similarly by male *lagopus*. Vegetation in nest sites and brood covers of the two species were similar. *L. leucurus* bred where shrubs were lacking and where rock fragments, ledges or rocky outcroppings provided adequate concealment. Extremely dry or wet sites, areas lacking floral variety, phenologically late biotopes and dense stands of shrubs were avoided by all species of ptarmigan.

ROBERT B. WEEDEN

GEOGRAPHICAL NAMES IN THE CANADIAN NORTH

The Canadian Board on Geographical Names has adopted the following names and name changes for official use in the Northwest Territories and Yukon Territory. For convenience of reference the names are listed according to the maps on which they appear. The latitudes and longitudes given are approximate only.

Chart 5427, Rankin Inlet
(Adopted October 2, 1958)

Barrier Islands	62°47′N.	92°18′W.
Ground Squirrel Island	62°43′	92°19′
Longspur Island	62°41′	92°11′
Sandy Islets	62°41′	92°09′
Broken Islands	62°41′	92°01′
Tiny Rock	62°43′	91°58′
South Shoals	62°42′	91°50′
Kind Islet	62°40′	91°56′
Hidden Rock	62°44′	91°48′
Fairway Shoals	62°42′	91°42′
Position Rock	62°42′	91°41′
Pin Rock	62°41′	91°46′
Quartzite Island	62°40′	91°00′
Hazy Islet	62°58′	91°00′
Isle of Cairns	62°39′	91°45′
Nedlik Island	62°39′	91°45′
Crane Island	62°38′	91°38′
False Knoll	62°49′	91°44′
Twin Knolls	62°48′	91°36′
Dry Cove	62°50′	91°48′
Nauja Cove	62°42′	91°14′

Scarab Point	62°48′	91°22′	
Outer Shoals	62°45′	91°38′	not Upper Shoals
Mittilik Island	62°42′	91°07′	not Metela Island

Dolphin and Union Strait, 87 SW and 87 SE

(Adopted November 6, 1958)

Read Island	69°12′N.	113°50′W.	
Name confirmation			
Read Island (trading post)	69°12′	113°50′	not Reid Island (trading post)

Fort Reliance, 75 L and 75 K

(Adopted November 6, 1958)

Marceau Lake	62°11′N.	110°26′W.
Face Lake	62°19′	110°08′
Fortress Island	62°40′	110°25′
Shelter Bay	62°49′	110°31′
Sunken Lake	62°59′	110°14′

Carmacks, 115 I

(Adopted November 6, 1958)

Mount McDade	62°07′N.	136°58′W.
Tritop Peak	62°13′	137°31′
False Teeth Creek	62°13′	137°48′

(Adopted January 15, 1959)

Five Finger Mountain	62°11′	136°18′
Milton Mountain	62°12′	136°15′
Berdoe Mountain	62°02′	136°13′
Deadwood Mountain	62°02′	136°12′
Rabe's Slough	62°06′	136°10′

MacKay Lake, 75 M

(Adopted November 6, 1958)

Plex Lake	63°07′N.	110°47′W.

Watson Lake, 105 A/2

(Adopted November 6, 1958)

Upper Liard (post office)	60°03′N.	128°54′W.

Chart 5457, Deception Bay

(Adopted November 6, 1958)

Red Point	62°15′N.	74°42′W.	
Bombardier Beach	62°07′	74°37′	
Neptune Island	62°14′	74°49′	not Siugaktuk Island nor Seeoogaktook Island
Arctic Island	62°14′	74°46′	not Kikilrayook Island
Egg Rock	62°12′	74°49′	not Tooloorangnak Rock
Moosehead Island	62°11′	74°44′	not Kikilrayookooloo Island
Table Mountain	62°11′	74°49′	not Kakahloo Mountain
Main Channel	62°14′	74°47′	not Itsigaksak Channel
East Channel	62°15′	74°44′	not Itsigaksak Channel
Careenage Arm	62°09′	74°44′	not Kangilksagayook Arm
Pointe Noire	62°12′	74°45′	not Black Point

Simpson-Liard, 95 SE

(Adopted December 4, 1958)

Nahanni Butte (locality)	61°06′N.	123°23′W.	not South Nahanni (settlement)
Name change			
Horn Plateau	61°58′	120°12′	not Horn Mountains

Aberdeen Lake, 66 SW and 66 SE

(Adopted December 4, 1958)

Fawn Lake	64°42′N.	100°15′W.	
Thelon Bluffs	64°31′	101°15′	
Muskox Hill	64°19′	102°41′	not Muskox Pingo

Peel River Aeronautical Chart 2078, Area of 106 and 116

(Adopted December 4, 1958)

Name change			
Hanna River	65°00′N.	128°50′W.	not East Mountain River

(Adopted April 3, 1959)
Altered application

Gayna River	65°28′	129°10′	

Dubawnt Lake, 65 NW and 65 NE

(Adopted December 4, 1958)

Retort Lake	63°57′N.	102°02′W.	

Dawson, 116 B and 116 C (E½)

(Adopted December 4, 1958)
Name change

Browns Creek	64°19′N.	140°52′W.	not Gates Creek

(Adopted April 3, 1959)

Antimony Mountain	64°18′	138°12′	

Name change

Antimony Creek	64°08′	138°29′	not Fish Creek

Foxe Peninsula 36 SW and 36 SE

(Adopted January 15, 1959)

Tunitjuak Island	64°17′N.	75°48′W.
Ooglukjuak Island	64°16′	75°42′
Innuksuk Island	64°18′	75°47′
Blades Island	64°17′	75°46′
Coatesworth Island	64°17′	75°47′
Nesfield Island	64°17′	75°48′
Honting Island	64°18′	75°47′
Dunne Island	64°17′	75°46′
Hume Island	64°17′	75°48′
Russell Island	64°17′	75°47′
Schioler Island	64°17′	75°49′
Bildfell Island	64°18′	75°47′
Gudmusson Island	64°17′	75°49′
Putaguk Island	64°17′	75°46′
Luke Island	64°17′	75°46′

(Adopted June 4, 1959)

Uningalik Lake	64°20′	76°53′
Ihalukpiuk Lake	64°20′	76°46′
Tessikakjuak Lake	64°18′	76°47′
Puvutaktuk Lake	64°19′	76°43′
Kingnait Hill	64°13′	76°34′
Shartowitok Bay	64°22′	76°10′

Cultus Creek 115 G/1

(Adopted January 15, 1959)
Name confirmation

Swanson Creek	61°17′N.	138°18′W.

Koidern 115 F/16

(Adopted January 15, 1959)

Wolf Lake	61°57′N.	140°03′W.

Root River 95 K

(Adopted January 15, 1959)

Trench Lake	62°30′N.	124°44′W.
Trench Creek	62°36′	124°45′
Dekale Creek	62°15′	124°41′
Pastel Creek	62°54′	125°11′
English Chief River	62°41′	124°00′
Landry Creek	62°56′	125°11′
Delorme Range	62°35′	125°15′
Iverson Range	62°35′	124°45′
Whittaker Range	62°40′	125°00′
Manetoe Range	62°10′	125°00′
Nahanni Plateau	62°05′	124°40′
Painted Mountains	62°40′	125°35′
Sombre Mountains	62°07′	125°40′
Thundercloud Range	62°30′	126°00′

Altered application

North Nahanni River	62°22′	124°00′

(Adopted April 3, 1959)
Name confirmation

Bell Heather Lake	62°20′	125°50′	not Bellheather Lake

Beuchat Lake 97 F/7
(Adopted January 15, 1959)

Beuchat Lake	70°03′N.	127°18′W.	

McKinlay Lake 97 F/9
(Adopted January 15, 1959)

McKinley Lake	70°25′N.	127°39′W.	

Malloch Hill 97 F/6
(Adopted January 15, 1959)

Malloch Hill	70°01′N.	127°57′W.	

Mamen Lake 97 F/24
(Adopted January 15, 1959)

Mamen Lake	70°30′N.	127°59′W.	

Neil Lake 107 E/16
(Adopted January 15, 1959)

Neil Lake	70°23′N.	128°02′W.	

Olivier Islands 117 D/1
(Adopted January 15, 1959)

Olivier Islands	69°07′N.	136°09′W.	

Halcro Point 97 D/26
(Adopted January 15, 1959)

Halcro Point	69°46′N.	123°09′W.	

Albert Bay 97 D/28
(Adopted January 15, 1959)

Albert Bay	69°48′N.	122°09′W.	

Hope Lake 107 C/7
(Adopted January 15, 1959)

Hope Lake	69°09′N.	135°10′W.	

Virginia Falls 95 F
(Adopted March 5, 1959)

Caribou Range	61°12′N.	125°47′W.	
Vengeance Range	61°45′	125°55′	
Dall Range	61°40′	125°30′	
Arnica Range	61°42′	125°17′	
Funeral Range	61°24′	124°58′	
Headless Range	61°19′	124°40′	
Tundra Ridge	61°51′	124°54′	
Rollingstone Creek	61°35′	125°34′	
Vera Creek	61°32′	125°16′	
Corridor Creek	61°51′	124°36′	
Sundog Creek	61°49′	124°14′	
Prairie Basin	61°43′	124°53′	
Cloudburst Basin	61°50′	125°36′	
First Canyon	61°16′	124°14′	
Second Canyon	61°19′	124°40′	
Third Canyon	61°21′	124°59′	
May Creek	61°23′	125°13′	not May River
Altered application			
Mary River	61°28′	125°05′	

Chart 5556 Bellot Strait and Approaches
(Adopted March 5, 1959)

Spar Islands	72°01′N.	95°23′W.	
Fox Islands	72°01′	94°23′	
Ditchburn Island	72°05′	94°02′	
Magpie Rock	72°00′	94°28′	
Halfway Island	72°00′	94°50′	not Half-Way Island nor Fox Island

Brands Island	71°58′	94°25′	not Brand Island
Depot Bay	72°01′	94°13′	not Transition Bay
Altered application			
Murchison Promontory	71°58′	94°47′	
Prince Regent Inlet	72°05′	93°47′	
Brentford Bay	71°55′	94°15′	

Bell River 116 P

(Adopted March 5, 1959)

Ogilvie Lake	67°42′N.	136°26′W.	
Long Lake	67°42′	136°25′	
Twin Lakes	67°43′	136°24′	
Two Ocean Creek	67°44′	136°25′	
Tundra Creek	67°44′	136°12′	
Bear Creek	67°44′	136°07′	
Berry Creek	67°27′	137°57′	
Lapierre House (locality)	67°23′	137°01′	not Le Piere's House (locality)
Symmetry Mountain	67°42′	136°13′	not Mount Symmetry
Whitefish Lake	67°08′	137°24′	not Fish Lake
Fish Creek	67°43′	136°16′	not Trout River
Sheep Creek	67°43′	136°16′	not South Fork (creek)
Nukon Creek	67°04′	137°40′	not John Nukon Creek
(Adopted May 7, 1959)			
Altered application			
Rat River	68°44′	136°00′	

Arctic Red River 106 N

(Adopted March 5, 1959)

Caribou Lake	68°00′N.	132°53′W.	
Sunny Lake	67°51′	132°41′	
Point Lake	67°49′	132°19′	
Sandy Lake	67°48′	132°13′	
Crossing Creek Lake	67°49′	132°01′	
Odizen Lake	67°45′	132°43′	
Tundra Lake	67°40′	133°42′	
Burnt Lake	67°32′	133°33′	
Beaver Lake	67°38′	133°23′	
Bathing Lake	67°40′	132°26′	
Deep Lake	67°40′	132°14′	
Jiggle Lake	67°40′	132°07′	
Dog Lake	67°24′	133°48′	
Rock Cove	67°19′	133°41′	
Whirl Lake	67°29′	133°14′	
Swan Lake	67°06′	133°40′	
Grassy Lake	67°29′	132°26′	
Benoit Creek	67°19′	132°15′	
Birch Lake	67°12′	132°33′	
Fat Rabbit Creek	67°13′	132°41′	
Pointed Hill	67°21′	132°32′	
In and Out Lake	67°33′	132°37′	
Rengleng River	67°48′	134°08′	
Wounded Bear Lake	67°39′	132°37′	
Hill Lake	67°59′	132°33′	
Fish Trap Lake	67°57′	132°13′	
Tregnantchiez Lake	67°46′	132°00′	
Lower Overflow Lake	67°46′	132°30′	
Upper Overflow Lake	67°44′	132°32′	
High Point Lake	67°53′	132°28′	
Otter Lake	67°55′	132°27′	
Loche Lake	67°36′	132°20′	
Big Stone Lake	67°32′	132°22′	
Bernadette Lake	67°26′	133°04′	
Midsqueezed Lake	67°29′	133°03′	
Nazon Lake	67°23′	133°25′	
Old Joe Lake	67°32′	133°12′	
Puzzle Lake	67°35′	133°10′	
Thad Lake	67°13′	133°17′	
Bushman Lake	67°07′	133°47′	
Ramey Lake	67°10′	133°47′	
Frog Creek Fount (lake)	67°13′	133°48′	

Frog Creek	67°11′	133°49′	
Nagle Lake	67°19′	133°32′	
Nagle Creek	67°23′	133°32′	
Cony Bay	67°25′	133°34′	
Tso Creek	67°26′	133°44′	
Taraltie Lake	67°22′	133°45′	
Three Forks Lake	67°24′	133°59′	
Rat Lake	67°25′	132°19′	
Swan Creek	67°00′	133°20′	not Bluefish Creek nor Swan Lake Creek
David Lake	67°50′	132°08′	not David's Lake
Clearwater Lake	67°33′	133°35′	not Clear Water Lake
Fishing Bear Lake	67°31′	133°16′	not Black Bear Lake
Islands Lake	67°25′	133°52′	not Island Lake
Pierre Lake	67°20′	132°56′	not Pierre's Lake
Adam Cabin Creek	67°11′	132°53′	not Adam's Cabin Creek
Rabbit Hay River	67°13′	132°45′	not Rabbiti Hay River
Rengleng Lake	67°42′	132°35′	not Rengleng Headwater Lake
Wood Bridge Lake	67°53′	132°10′	not Wood-Bridge Lake
Barney Lake	67°28′	133°01′	not Barney's Lake
Big Woman Lake	67°23′	133°18′	not Bigwoman Lake
Point Cut Lake	67°32′	133°23′	not Point-Cut Lake
Ernest Lakes	67°11′	133°34′	not Ernest's Lakes
Mission Lake	67°13′	133°37′	not Mission's Lake
Tso Lake	67°25′	133°41′	not Tso (Yellow) Lake

Mahony Lake 96 F

(Adopted March 5, 1959)

White Water Lily Lake	65°46′N.	124°08′W.	

Porcupine River 116 NW and 116 NE

(Adopted April 3, 1959)

Canalaska Mountain	67°22′N.	141°00′W.	
Rampart Mountain	67°21′	140°57′	
Johnson Creek	66°58′	137°45′	
Burnthill Creek	66°41′	138°05′	
Cody Creek	66°32′	138°21′	
Fishing Branch (creek)	66°27′	138°32′	
Ellen Creek	66°42′	137°54′	
Lone Mountain	67°17′	139°35′	
Sharp Mountain	67°12′	138°49′	
White Snow Mountain	67°02′	138°35′	
Heart Mountain	66°57′	139°03′	
Bear Cave Mountain	66°30′	139°15′	
Mason Lake	66°26′	138°55′	
Cody Hill	66°33′	138°20′	
Whitestone (locality)	66°31′	138°05′	
Cadzow Lake	67°34′	139°02′	not Fish Lake
Schæffer Lake	66°44′	137°58′	not Shæffer Lake
Schæffer Creek	68°00′	140°12′	not Schæfer Creek
Rat Indian Creek	67°34′	137°23′	not Indian (Crow Flat Indian Creek)
Pine Creek	66°51′	137°49′	not Little Porcupine River
Miner River (For southern part to junction of Whitestone River)	66°30′	138°24′	not Porcupine River
Whitestone River	66°30′	138°24′	not East Porcupine River
Chance Creek	66°25′	138°24′	not Canoe River
Rube Creek	66°36′	138°11′	not Mason Creek

King Christian Island 69 SW and 69 SE

(Adopted April 3, 1959)

Hassel Sound	78°00′N.	98°15′W.	
Robert Harbour	76°35′	104°04′	
Cameron Bay	76°30′	103°43′	
Shamrock Bay	76°36′	99°56′	
Young Inlet	76°33′	99°15′	
Water Sound	76°35′	97°55′	
Pelham Bay	76°46′	96°49′	
Hawker Bay	76°48′	96°27′	

Hingston Harbour	76°17′	101°57′	
Oliver Harbour	76°25′	101°20′	
Dampier Bay	76°15′	101°08′	
Driftwood Bay	76°02′	98°02′	
Grosvenor Island	77°02′	103°38′	
Cape Davis	76°39′	103°52′	
Cape Fleetwood	76°34′	103°34′	
Helena Island	76°39′	101°04′	
Hosken Islands	76°43′	100°13′	
Morshead Point	76°37′	100°11′	
Sherard Osborn Island	76°44′	99°45′	
Cape Mary	76°38′	99°42′	
Cape Sophia	76°36′	99°07′	
Annie Point	76°31′	99°03′	
Russell Island	76°54′	96°52′	
Hornby Island	76°53′	97°04′	
Hyde Parker Point	76°46′	97°08′	
Charles Island	77°01′	96°41′	
Norah Island	76°59′	96°35′	
Herbert Island	76°49′	96°39′	
Loney Point	76°49′	96°48′	
Cracroft Island	76°38′	96°46′	
Cape Fortune	76°28′	103°18′	
Charles Point	76°26′	102°58′	
Cape Clerk	76°25′	102°56′	
Cape Head	76°05′	102°21′	
Kerswill Island	76°21′	100°42′	
Chubb Point	76°13′	99°55′	
Arran Mountain	77°02′	96°05′	
Mount Edgecombe	76°32′	100°40′	
Mount Lockyer	76°30′	100°47′	
Grogan Morgan Range	76°24′	100°25′	
Jeffries Range	76°05′	99°30′	
Humphries Hill	76°27′	99°35′	
Greenwich Hill	76°20′	98°19′	
Cockscomb Peak	76°07′	98°05′	
Sir William Parker Strait	76°35′	100°45′	not Parker Strait
Carey Harbour	76°29′	98°20′	not West Water Sound
Hungry Bay	76°37′	96°10′	not Sophia Bay
Reindeer Bay	76°15′	98°05′	not Rein-Deer Bay
Cape Robert Smart	76°34′	101°43′	not Cape Smart
Mackay Point	76°38′	101°32′	not Point Mackay
Ashington Point	76°43′	99°28′	not Point Ashington
Webb Point	76°41′	99°41′	not Point Webb
Ricards Island	76°39′	99°04′	not Richards Island nor Rickards Island
Spit (Kate) Island	76°48′	97°07′	not Kate Island nor Spit Island
Cape Sir John Franklin	76°43′	96°49′	not Cape Franklin
Milne Peninsula	76°47′	96°33′	not Milne Island
Sophie Point	76°21′	102°59′	not Point Sophie
Francis Herbert Point	76°30′	100°55′	not Herbert Point
Phillipps Island	76°17′	100°57′	not Phillipps Peninsula
Palmer Point	76°08′	99°49′	not Point Palmer
Grant Point	76°04′	100°00′	not Point Grant
Emma Point	76°31′	99°11′	not Point Emma
Hyde Parker Island	76°25′	97°22′	not Parker Island
Green River	76°22′	98°02′	not River Green
Mount Blanche	76°44′	96°29′	not Blanche Mount
Mount Hawker	76°45′	96°21′	not Hawker Mount
Mount Wilmot	76°25′	103°18′	not Mount Wilmott
Mount Johnny Barrow	76°31′	96°03′	not Sir John Barrows Monument (mountain) nor Barrow Monument (mountain) nor Mount Sir John Barrow

Chart 5532 Mill Island to Winter Island

(Adopted April 3, 1959)

Altered application

Dunne River	64°59′N.	78°04′W.

Wrigley 95 O

(Adopted April 3, 1959)

Rocky Island	63°15′N.	123°34′W.	
Williams Peak	63°23′	123°16′	not MY's Peak
Altered applications			
Roche-qui trempe-à-l'eau (hill)	63°18′	123°39′	
Cap Mountain	63°24′	123°12′	
Mount Kindle	63°21′	123°12′	

Markham Inlet 29 A (N½), 19 A (N½), and 9 A (N½)

(Adopted April 3, 1959)

Mount Hilgard	82°22′N.	63°45′W.	not Mount Olga
(Adopted May 7, 1959)			
Patterson River	82°38′	63°30′	
Grant River	82°26′	64°40′	not Upper Wood River
North Wood Glacier	82°20′	65°45′	not Allix Glacier
South Grant Glacier	82°24′	65°40′	not Grant Glacier
North Grant Glacier	82°28′	65°45′	not Northern Grant Glacier
Mount Patterson	82°33′	64°41′	not Patterson Mount
Cache Creek	82°37′	63°24′	not Cache River
Eugene Glacier	82°14′	66°45′	not Peguy Glacier
Grant Ice Cap	82°25′	66°20′	not Pavy Icefield
Mount Wood	82°22′	66°12′	not Allix Peak
South Wood Glacier	82°19′	66°05′	not Pavy Glacier
Mount Eugene	82°24′	66°05′	not Mount Arthur Eugene nor Allix Mountain

Fort Franklin 96 G

(Adopted April 3, 1959)

Lost Hill Lake	65°40′N.	123°23′W.	
Man Drowned Himself Lake	65°41′	123°15′	
Whitefish River	65°32′	124°00′	
White Losh Lake	65°48′	123°28′	not White Lock Lake
Tuitatui Lake	65°47′	123°15′	not Tui Ta Tui Lake nor Lake Among Many Lakes
Tatui Lake	65°57′	123°05′	not Ta Tui Lake nor Lac des Maringouins
Kekwinatui Lake	65°38′	123°08′	not Kequinatui Lake
Porcupine River	65°02′	123°43′	not Rivière Poisson-Blue

Eagle River 116 I

(Adopted April 3, 1959)

Moose Lake	66°12′N.	136°26′W.	
Eagle Plain	66°15′	137°00′	

Little Buffalo River 85 A

(Adopted April 3, 1959)

Salt Mountain	60°02′N.	112°26′W.	
Lake of the Grave	60°12′	113°39′	
David Pond	60°10′	113°36′	
Badwater Creek	60°45′	113°30′	
Preble Creek	60°14′	113°12′	
Seton Creek	60°11′	112°43′	
Lobstick Creek	60°04′	112°37′	
Landry Creek	60°44′	112°52′	
Sawmill Island	60°03′	112°12′	not Big Island
Grand Detour	60°22′	112°42′	not Le Grand Detour
(Adopted June 4, 1959)			
Hook Lake	60°40′	112°45′	
Name confirmation			
Big Rat Slough (for feature in C-4 of name sheet)	60°45′	112°56′	not Laundry River

Old Crow 116 N (E½) and 116 O

(Adopted April 3, 1959)

Old Crow Flats	67°56′N.	139°53′W.	
Pear Lake	67°16′	140°36′	
Frog Lake	67°30′	140°18′	
Twin Lake	67°18′	140°20′	

Tack Lake	67°28′	139°31′	
Mount Schaeffer	67°46′	139°43′	not Mount Schaefer nor Mount Shaeffer nor Schaeffer Mountain
Little Flat Creek	67°50′	139°23′	not Little Flats Creek

Johnson Bay 107 E/3

(Adopted April 3, 1959)

Johnson Bay	70°01′N.	129°29′W.	

Dezadeash 115 A

(Adopted May 7, 1959)

Kathleen Lake	60°35′N.	137°18′W.	
Louise Lake	60°32′	137°27′	
Lower Kathleen Lake	60°37′	137°13′	not Sukaye Lake

Leith 86 E

(Adopted May 7, 1959)

Kway Cha Lake	65°27′N.	118°33′W.	
Chelay Lake	65°14′	119°26′	
Naga Lake	65°12′	119°11′	
Tuchay Lake	65°15′	119°08′	
Yen Lake	65°35′	118°30′	
Yeta Lake	65°37′	118°48′	
Kechinta Island	65°13′	118°38′	
Hloo Channel	65°41′	118°26′	
Tla Bay	65°39′	118°21′	
Sawmill Bay	65°43′	118°48′	
Name confirmations			
Hottah Lake	65°04′	118°29′	not Intsay Tui (lake)
Fishtrap Lake	65°27′	118°25′	not Kway Tui (lake)
Yanik Lake	65°22′	118°36′	not Kwovee Tui (lake)
Bear Island	65°33′	119°59′	not Sa Doo (island)
Camsell River	65°40′	118°07′	not Nakazee Day (river)
Leith Peninsula	65°38′	119°15′	not Ay Wee (peninsula)

Boothia 57 NW and 57 NE

(Adopted May 7, 1959)

Pasley River	70°32′N.	95°48′W.	
Chartrand Lake	70°04′	94°20′	

Somerset Island 58 SW and 58 SE

(Adopted May 7, 1959)

Oliver Lake	72°05′N.	94°09′W.	not Little Fish Lake nor Ekalludliadjuak Lake nor Ikaluliajuk Lake

Anderson River 97 SW and 97 SE

(Adopted May 7, 1959)

Outwash River	69°33′N.	120°42′W.	

Sibbeston Lake 95 G

(Adopted May 7, 1959)

Bay Creek	61°06′N.	123°07′W.	
Fishtrap Creek	61°14′	123°40′	
Overflow Creek	61°09′	123°38′	
Windy Creek	61°15′	123°59′	
Bluefish Lake	61°11′	123°19′	
Mid Lake	61°32′	123°41′	
Ram Plateau	61°41′	123°53′	
Martin Hills	61°47′	122°10′	
Silent Hills	61°33′	123°38′	
Yohin Ridge	61°09′	123°53′	
Bluefish Creek	61°02′	123°26′	not Bluefish River
Tetcela River	62°02′	123°32′	not Little Nahanni River

Pelly River 105 NW and 105 NE

(Adopted May 7, 1959)

Name confirmation

Trilobite Lakes	62°04′N.	128°24′W.	not Flat Lake

Alert Area 19 A

(Adopted May 7, 1959)

Sickle Point	82°30′N.	62°03′W.	
Mann River	82°29′	61°39′	not Pavy River
Cairn Butte	82°31′	62°14′	not Butte-au-Cairn
Dean Hill	82°26′	62°06′	not Mount Danielo
Jolliffe Bay	82°32′	62°38′	not Williams Island Bay
Cape Jolliffe	82°31′	62°47′	not Williams Island Cape
Hilgard Lake	82°26′	63°09′	not Desgoffe Lake

Norwegian Bay 59 SW and 59 SE

(Adopted May 7, 1959)

Bere Bay	76°53′N.	94°15′W.	
Wilmer Bay	76°45′	93°30′	
Skred Bay	76°37′	89°47′	
Ren Bay	76°42′	89°30′	
Cross Bay	76°34′	89°34′	
Goose Fiord	76°36′	88°35′	
Port Refuge	76°18′	94°43′	
Prince Alfred Bay	76°17′	93°20′	
Norfolk Inlet	76°28′	91°05′	
Eidsbotn (fiord)	76°08′	91°00′	
Sandspollen (fiord)	76°09′	90°15′	
West Fiord	76°05′	90°00′	
Seal Bay	76°29′	89°25′	
McLeod Head	77°47′	95°00′	
Goose Point	77°51′	88°17′	
Little Bear Cape	77°40′	88°16′	
Cape Butler	77°28′	95°52′	
Cape Ursula	77°08′	95°20′	
Belcher Island	77°26′	93°47′	
Fielder Point	76°54′	93°43′	
Tucker Point	76°44′	93°16′	
Cape Separation	76°36′	93°13′	
De Lacy Head	76°51′	90°02′	
Devil Island	76°31′	90°32′	
Blubber Point	76°37′	89°42′	
Dyer Island	76°19′	95°20′	
Margaret Island	76°03′	94°50′	
Porden Point	76°14′	93°42′	
Hornby Head	76°17′	93°43′	
Cape Turnback	76°27′	89°21′	
Cape Vera	76°15′	89°17′	
Olsen Island	76°27′	88°32′	
Mount Nicolay	77°45′	94°58′	
Mount Greenwich	77°34′	94°20′	
Blanche Mountain	76°37′	91°50′	
Triton Bay	76°35′	92°30′	not Triton Inlet nor Tritton Inlet nor Tritton (Tricton) Inlet
Walrus Fiord	76°30′	88°51′	not Hvalrosfjorden (inlet) nor Walrus Fjord
Bay of Woe	76°25′	89°09′	not Bay of Woes
Cape Ludwig	77°56′	95°08′	not Cape Ludvig
Northeast Point	77°44′	93°20′	not North-East Point nor North East Point nor North Eastern Point
Cape Briggs	77°03′	95°45′	not Cape Ekins
Nordstrand Point	77°09′	89°02′	not Nordstrand (point)
Cape Disraeli	76°42′	93°15′	not Cape D'Israeli
North Kent Island	76°41′	90°17′	not Kent Island
Robb Peninsula	76°20′	95°16′	not Robb's Peninsula
Point Little	76°06′	95°13′	not Cape Little
Crozier Point	76°02′	95°04′	not Crozier Cape
Colin Archer Peninsula	76°15′	90°30′	not Archer Peninsula
Cape Harrison	76°29′	90°35′	not Harrison Island
Prince Edward Point	76°29′	90°04′	not Prince Edward Cape
Calf Island	76°27′	89°38′	not Kalven Vendomkap (island)
Cape Hawes	76°18′	89°28′	not Hawes Point
Walrus Cape	76°23′	88°59′	not Summer Point